The Indus Enigma

Genes, Scripts, and the Contested Origins of South Asian Civilization

A Network Horizon Companion Volume

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Introduction

A Different Kind of Problem

The five volumes of the Network Horizon series examined a recurrent empirical pattern: technologies of fundamental adaptive importance — ceramics, the wheel, horse domestication, copper metallurgy — arising independently in multiple regions rather than diffusing from a single point of origin. The present volume departs from that programme in a way that needs to be stated plainly before a single piece of evidence is introduced.

The Indus Valley Civilisation (also called the Harappan Civilisation), which flourished across the Indus and Ghaggar-Hakra river systems of present-day Pakistan and northwest India from approximately 3300 to 1300 BCE, poses a different kind of question. It is not a case of convergent invention in multiple regions; it is a single civilisation whose population history, linguistic affiliation, and relationship to later South Asian populations remain genuinely contested — contested not merely in the ordinary sense that all historical questions admit of debate, but contested in a manner that is actively and explicitly entangled with contemporary political and religious identity claims in South Asia. A reader arriving at this volume expecting another application of the Network Horizon axiomatic apparatus of Volume V will not find one. What is offered instead is a structural diagnosis of why this particular question resists resolution, organised around four independent analytical engines, in the same spirit of multi-source convergent evidence that the rest of the series employs, but without the series' central theoretical claim (polycentric emergence) as the object of inquiry.

Note 0.1: Why This Volume Stands Outside the Network Horizon Series Proper

The Network Horizon model of Volume V is built to discriminate between two specific hypotheses about technological origins: independent invention versus diffusion from a single source. Neither hypothesis is the right shape for the Indus question. No one disputes that the Indus Valley Civilisation was a single, geographically bounded urban tradition; the disputes concern its population's genetic relationship to later South Asians, the linguistic family of its undeciphered script, and the causal relationship between its decline and the arrival of Steppe-derived populations in the subcontinent. These are questions of *population history and identity*, not questions of *technological emergence*, and the axiomatic apparatus of Chapter 2 of Volume V does not apply to them. This volume is offered as a companion piece — methodologically related in its commitment to multi-source convergent evidence and its refusal to adjudicate beyond what the evidence supports, but addressed to a structurally different question.

Three Kinds of Claim That Must Not Be Confused

The single methodological commitment that organises every chapter of this study is a distinction that is easy to state and difficult to maintain under the pressure of a politically charged debate: a genetic finding, a linguistic finding, and an identity claim are three different kinds

of statement, governed by three different evidentiary standards, and a finding of one kind does not validate or invalidate a claim of another kind.

Definition 0.1: The Three-Tier Distinction

Tier 1 — Genetic ancestry: a quantitative statement about the proportion of an individual's or population's genome that traces to one or more reference ancestral populations, estimated from ancient DNA using methods such as f-statistics and admixture modelling (`qpAdm`). Genetic ancestry is a property of biological descent; it is estimated with reportable confidence intervals and is, in principle, independently replicable from new samples.

Tier 2 — Language family affiliation: a qualitative classification of a language as belonging to a specific family (e.g. Indo-European, Dravidian), established through the comparative method of historical linguistics — systematic sound correspondences, shared morphological paradigms, and reconstructed proto-forms. Language affiliation is a property of cultural transmission, learned anew by each generation; it is not encoded in DNA and cannot be inferred from a genome, however well sampled.

Tier 3 — Identity and political claims: assertions about which present-day group is the legitimate heir, ethnic descendant, or cultural continuation of an ancient population. Identity claims may draw on Tier 1 and Tier 2 findings as supporting evidence, but they are themselves neither genetic nor linguistic statements; they are interpretive and political acts, evaluated by criteria — historical continuity, self-identification, cultural practice — that are external to both population genetics and historical linguistics.

Proposition 0.1: The Non-Transitivity of the Three Tiers

No valid inference proceeds directly from a Tier 1 finding to a Tier 2 conclusion, or from either to a Tier 3 claim, without additional premises external to the originating discipline. Specifically: (a) a population's ancestry proportions do not determine which language(s) its members spoke, since language shift without substantial genetic replacement is a well-documented historical process and genetic replacement without language shift is equally well documented; (b) a language family's geographic origin does not determine the ancestry of all its present-day speakers, since language spread typically involves both demic diffusion and elite or cultural transmission in proportions that vary by case and must be independently established; (c) neither (a) nor (b) determines which contemporary group, if any, holds privileged interpretive or political claim to an ancient population's legacy, since that determination depends on continuity criteria that are conventionally and politically, not empirically, defined. Violations of this proposition — treating a Tier 1 finding as if it settled a Tier 2 or Tier 3 question — recur throughout the public reception of Indus Valley genetics, as Chapter 3 documents in detail for a specific, well-documented instance.

This is not a merely academic nicety. As Chapter 3 of Part I shows in detail, the conflation of Tier 1 and Tier 2 claims is precisely the move that converted a technical population-genetics finding from Rakhigarhi into a contested public assertion about the language spoken by Bronze Age Indus city-dwellers — an assertion that the genetic data cannot, in principle, support, and that several of the finding's own co-authors explicitly rejected.

The Four Analytical Engines

Following the methodological architecture of the companion volume on the origin of the wheel, this monograph organises its evidence around four independent analytical engines,

each addressed to a different evidentiary stream and each capable, in principle, of being wrong without invalidating the others.

Note 0.2: The Four Engines and What Each Can and Cannot Establish

The genomic engine (Part I) examines what ancient DNA from Indus Valley and surrounding sites actually establishes about population ancestry and its relationship to later South Asian populations, and — in equal measure — what it cannot establish, particularly regarding language and identity.

The linguistic engine (Part II) examines the state of Indus script decipherment and the unresolved question of which language family, if any, the Indus Valley Civilisation's population spoke, including the politically inflected Dravidian-versus-Indo-Aryan dispute over linguistic priority in the subcontinent.

The archaeological and chronological engine (Part III) examines the civilisation's documented chronology, the contested causal role of climate change (the so-called "4.2 ka event") in its decline, and the material evidence for cultural continuity versus discontinuity across the Bronze-to-Iron Age transition.

The computational epigraphy engine (Part IV) examines recent (2024–2025) machine-learning approaches to Indus script decipherment, why they have not succeeded, and what their specific mode of failure reveals about the structural difficulty of the decipherment problem as distinct from a mere shortage of computational effort.

Each engine is evaluated on its own evidentiary terms. The volume's closing chapter does not attempt to force the four engines into a single unified verdict, because — as Part I argues at length — the temptation to do exactly that, prematurely and for reasons external to the evidence, is itself the central phenomenon this volume documents.

Part I

The Genomic Engine

Chapter 1

The Three-Cline Model: Narasimhan et al. (2019)

1.1 The Study and Its Scale

In September 2019, *Science* published "The formation of human populations in South and Central Asia" (Narasimhan, Patterson, Moorjani et al.), reporting genome-wide data from 523 ancient individuals spanning roughly 8,000 years of South and Central Asian prehistory. The study, led by the Reich Laboratory at Harvard Medical School in collaboration with dozens of regional institutions, remains — as of this volume's composition — the single largest ancient-DNA dataset assembled for the region, and its framework for describing South Asian population history has become the reference point against which subsequent and competing claims, including the Rakhigarhi finding discussed in Chapter 2, must be situated.

Definition 1.1: The Three Ancestral Reference Populations. Narasimhan et al. model South and Central Asian ancient and modern populations as deriving, in varying proportions, from three principal ancestral sources:

(i) **AASI** (Ancient Ancestral South Indian): a deeply diverged South Asian hunter-gatherer lineage, distinct from West Eurasian and East Asian lineages, attested only indirectly through admixture signals in later populations rather than through a directly sampled source population.

(ii) **Indus Periphery Cline**: a cluster of individuals, sampled from sites at the geographic and cultural periphery of the Indus Valley Civilisation (since direct sampling within the core Indus urban sites was not yet available to this study), whose ancestry is predominantly Iranian-farmer-related with an AASI admixture component, and who show *no detectable Steppe ancestry* prior to approximately 2000 BCE.

(iii) **Central_Steppe_MLBA** (Middle-to-Late Bronze Age): a population genetically continuous with the Yamnaya-derived Steppe pastoralist expansion already documented in Bronze Age Eastern Europe, which the study traces moving via Central Asia into South Asia beginning around 4,000 years before present (i.e. from approximately 2000 BCE).

1.2 The Temporal Sequence

The study's central historical claim is not a static ancestry snapshot but a documented *sequence* of three successive admixture clines, each datable relative to the others by the ancient samples in which it appears.

Finding 1.1: The Two-Way Clines and Their Chronology. Prior to approximately 2000 BCE, the Indus Periphery Cline individuals show *no detectable Steppe ancestry whatsoever* — the cline at this stage is a two-way mixture of Iranian-farmer-related and AASI-related ancestry only. Beginning around 2000 BCE, and continuing through roughly 1000 BCE, a second cline emerges (the "Steppe Cline"), formed as Central_Steppe_MLBA-derived populations expanded into the subcontinent and admixed with Indus Periphery Cline descendants. The two main ancestral source populations of modern South Asians — conventionally labelled ANI (Ancestral North Indian) and ASI (Ancestral South Indian) in the population-genetics literature predating this study — are shown to have themselves formed *after* the Indus Valley Civilisation's decline, as Indus Periphery Cline descendants mixed respectively with northern Steppe-derived groups and with southern and eastern AASI-rich groups. A third, "Modern Indian Cline" succeeds these two, reflecting further admixture among their descendants up to the present.

This sequence carries a direct implication for the population genetics of the Indus Valley Civilisation specifically, stated by the study with a clarity that subsequent public debate, as Chapter 3 documents, did not always preserve.

Corollary 1.1: The Indus Periphery Cline Predates Steppe Contact. Since the Indus Periphery Cline individuals sampled by Narasimhan et al. show no detectable Steppe ancestry before approximately 2000 BCE — a date that falls within or after the civilisation's documented decline phase (Chapter 7) rather than during its mature urban phase (2600–1900 BCE) — the population genetics of the Indus Valley Civilisation *at its height* are, on the data available to this study, free of Steppe-pastoralist genetic input. This is consistent with, though not by itself sufficient to establish, the proposition that the IVC's core urban population was demographically and culturally independent of the later Indo-Aryan-associated Steppe migration into South Asia — a proposition compatible with several different positions in the broader Indo-Aryan migration debate, as §1.4 below discusses.

1.3 What "Indus Periphery" Means, and Why It Matters

A methodological point requires emphasis before the chronological argument can be properly weighed: at the time of this study's publication, no ancient DNA had been successfully recovered from any individual buried within a core urban Indus Valley site itself (Mohenjo-daro, Harappa, Dholavira, or comparable major centres). The "Indus Periphery Cline" designation is precise and limiting: these are individuals from sites in Iran, Turkmenistan, and other locations at the documented periphery of the IVC's trade and cultural network, genetically consistent with, but not directly sampled from, the IVC's urban core.

Note 1.1: The Sampling Gap This Study Could Not Close. Hot, humid South Asian climates are exceptionally unfavourable to ancient DNA preservation relative to the cold, dry conditions (Eurasian steppe, high-altitude sites) where ancient DNA recovery has been most successful. This is not a flaw specific to Narasimhan et al.; it is a structural constraint on the entire field's ability to characterise the Indus Valley Civilisation's population genetics directly, and it is the same constraint that makes the single successfully sequenced Rakhigarhi individual, discussed in the next chapter, disproportionately significant — and disproportionately fragile as a sole evidentiary pillar.

1.4 Independent Corroboration: The Brahmin Ancestry Signal

Narasimhan et al. report a finding that functions, within their own study, as an internal cross-check on the Steppe-migration chronology independent of the Indus Periphery dating itself.

Finding 1.2: Priestly-Caste Ancestry as an Independent Line of Evidence. The study reports that individuals identified as Brahmins — the traditional custodians of Sanskrit liturgical practice in South Asia — show, on average, a higher proportion of Steppe-related ancestry than a simple two-way ANI/ASI admixture model would predict for their geographic location and caste-cline position. The authors present this as an independent line of evidence, additional to the Steppe ancestry profile's resemblance to Bronze Age Eastern Europe (itself argued to track the shared ancestral source of the Indo-Iranian and Balto-Slavic language branches), for associating the historical Indo-Aryan-speaking populations of South Asia with the Steppe-derived demographic component specifically, rather than with the earlier Indus Periphery component.

This finding requires the same Tier-distinction caution articulated in Definition 0.1: an elevated Steppe-ancestry signal in a present-day caste group historically associated with Sanskrit transmission is a Tier 1 (genetic) finding that *correlates with* a Tier 2 (linguistic) tradition; it does not, by itself, prove that Steppe migrants *introduced* Sanskrit's ancestral language to South Asia, since the correlation is consistent with several different historical mechanisms (elite transmission with limited genetic replacement, genetic replacement with subsequent endogamous caste maintenance, or some combination), each carrying different implications for the broader migration debate. The authors' own phrasing — "independent line of evidence ...for a Bronze Age Steppe origin for South Asia's Indo-European languages" — is a carefully qualified Tier 1-to-Tier 2 inference, explicitly flagged as inferential rather than as a directly observed fact; the qualification matters for what follows in Chapter 3.

Chapter 2

Rakhigarhi: One Genome and Its Limits

2.1 The Site and the Sample

Rakhigarhi, located in Haryana, India, is the largest known Indus Valley Civilisation site by total archaeological footprint, with estimates of its extent ranging from approximately 80–100 hectares for the five closely integrated Mature-phase mounds (RGR-1 through RGR-5) to 300–350 hectares for the full site perimeter following the identification of two additional outlying mounds by the Archaeological Survey of India in 2014 — a total that substantially exceeds the most commonly cited area estimate for Mohenjo-daro (approximately 250 hectares), though both sites carry significant uncertainty given that neither has been fully excavated. Excavations led by archaeologist Vasant Shinde of Deccan College, Pune, between 2011 and 2016, recovered numerous burials, and a sustained effort was made to extract ancient DNA suitable for genome-wide sequencing — an effort whose difficulty cannot be overstated given the climatic preservation constraints discussed in Note 1.1.

Note 2.1: A Single Successful Extraction From Sixty Burials. Of 61 skeletons excavated at the Rakhigarhi burial site, only one yielded ancient DNA of sufficient quality and coverage for genome-wide analysis. This is reported consistently across primary and secondary sources on the study and is not in dispute; it is a measure of the technical achievement involved in recovering any usable signal at all from a tropical, humid burial environment, and equally a measure of how much inferential weight a single individual's genome is being asked to bear.

2.2 The Published Findings

The results were published in two companion papers in 2019: a genomics-focused paper in *Cell* ("An Ancient Harappan Genome Lacks Ancestry from Steppe Pastoralists or Iranian Farmers", Shinde, Narasimhan, Rai et al.) and contributed data to the broader Narasimhan et al. *Science* paper discussed in Chapter 1, with which the Rakhigarhi individual's genetic profile is consistent.

Finding 2.1: The Rakhigarhi Genome's Ancestry Profile. The single successfully sequenced Rakhigarhi individual, dated to approximately 2500 BCE (within the IVC's mature urban phase), shows ancestry consistent with the Indus Periphery Cline of Definition 1.1: a mixture of Iranian-farmer-related and AASI-related ancestry, with *no detectable ancestry from Steppe pastoralists or from Anatolian or western Iranian farmers* — the latter exclusion distinguishing the Indus Periphery source specifically from the Near Eastern farming populations that contributed to West Eurasian agricultural spread by a different route. The study's own published conclusion states that this pattern is consistent with farming in South Asia having "lo-

cal" roots — i.e. developing through indigenous population processes and selective adoption of farming practices rather than through large-scale population replacement by farming migrants from the West, distinct from the question of later Steppe-pastoralist arrival addressed by Narasimhan et al.'s broader dataset.

This finding, read narrowly and in the terms the paper itself states, is consistent with — not contradictory to — the Narasimhan et al. chronology of Chapter 1: an Indus Periphery individual at 2500 BCE showing no Steppe ancestry is exactly what the three-cline model predicts, since the Steppe Cline does not appear in the dataset until after approximately 2000 BCE. The single Rakhigarhi genome is, in this sense, a single additional data point consistent with a chronology the larger Narasimhan et al. dataset had already established from dozens of other Indus Periphery individuals — not an independent or contradictory finding, despite how it was subsequently characterised in public discussion, as Chapter 3 documents.

2.3 The Statistical Weight One Genome Can Bear

Proposition 2.1: The Generalisability Limit of a Single Sample. A single ancient individual's genome provides direct evidence only about that individual's own ancestry; it cannot, without further assumption, characterise the ancestry distribution of the population from which the individual was drawn, since ancient populations — like modern ones — are not guaranteed to be genetically homogeneous. The published study itself states this limitation explicitly, noting that neither a single sample nor even the broader gradient of approximately a dozen Indus-Periphery-associated individuals available to Narasimhan et al. can "fully characterise a cosmopolitan" population such as the Indus Valley Civilisation's, whose urban centres show material-culture evidence (discussed in Part III) of extensive long-distance trade contact and plausibly correspondingly diverse population composition. The Rakhigarhi individual's ancestry profile is evidence about what was *present* in the IVC population at 2500 BCE; it is considerably weaker evidence about what was *absent*, since a single sample's failure to show a given ancestry component is consistent both with that component's genuine absence from the population and with its presence at a frequency too low for a one-individual sample to detect.

This is not a criticism unique to Rakhigarhi or to its authors — it is the standard, well-understood limitation of any single-sample ancient-DNA finding, openly acknowledged within the publication itself. It becomes consequential only at the point, examined in the next chapter, where the finding's public presentation outran what the publication itself claimed.

Chapter 3

The Interpretive Fracture: Science, Press Conference, and Public Reception

3.1 Two Papers, One Press Event, Divergent Messages

The Rakhigarhi findings did not enter public discourse through the technical papers alone. A press conference convened around the findings' release became, independently of the papers' content, a documented locus of the conflation this study's Introduction warns against — and the documentation is unusually clear because several of the study's own co-authors are on record disputing the press conference's framing.

Case Study 3.1: The Press Conference Claims

At the press conference announcing the findings, lead archaeologist Vasant Shinde is reported, across multiple independent press accounts (*Outlook India*, *Swarajya*, *The Economic Times*, *Peoples Dispatch*), to have stated that the genetic evidence demonstrated: (a) an "indigenous development" of South Asian populations without large-scale migration from Central Asia, extending continuously from the hunter-gatherer period through to the present; (b) that there was "no Aryan invasion and no Aryan migration"; and, in at least one widely reported instance, (c) that the Indus Valley population "spoke Sanskrit". Claim (a) is a defensible, if strongly stated, reading of the Tier 1 genomic evidence specifically for the pre-2000-BCE IVC population, consistent with Finding 2.1 and Corollary 1.1. Claim (b) substantially overstates what a single 2500-BCE genome can establish about migration events the broader Narasimhan et al. dataset dates to *after* 2000 BCE — the Rakhigarhi finding is simply silent on, not contradictory to, later Steppe migration, since the individual sequenced lived centuries before the period the migration claim concerns. Claim (c) is a Tier 1-to-Tier 2 inference of exactly the invalid form Proposition 0.1 identifies: no ancient genome, however completely sequenced, encodes the language its bearer spoke.

3.2 The Co-Authors' Response

What distinguishes this case from many instances of media oversimplification of scientific findings is that the conflation did not occur primarily in press translation of a technical paper; it occurred in a statement attributed to the study's own lead author, and other co-authors are documented as having responded directly and critically.

Note 3.1: Documented Co-Author Disagreement. Multiple press accounts report that other co-authors of the Rakhigarhi study — including geneticist Niraj Rai (Birbal Sahni Institute of Palaeosciences, Lucknow) and population geneticist Vagheesh Narasimhan (the same Narasimhan of Chapter 1's *Science* paper) — distanced themselves from the language-related claim specifically, with one account characterising their response as pointing out, "politely", that the data did not support Shinde's contention regarding language. This is, within the normal conduct of collaborative science, an unusually public instance of co-authors disputing a colleague's characterisation of their own joint publication's findings, and it is documented closely enough in independent press sources — not merely asserted by one side — that it can be treated as an established fact about the controversy's structure, independent of which substantive position in the broader migration debate a reader finds more persuasive.

3.3 The Institutional Context

A further layer of the controversy, documented in Indian press coverage (*Peoples Dispatch*, *NewsClick*) rather than in any scientific source, concerns Shinde's documented institutional affiliation with Vijnana Bharati, described in these sources as the science-outreach wing of the Rashtriya Swayamsevak Sangh (RSS), the Hindu nationalist organisation that is the ideological parent body of India's ruling Bharatiya Janata Party.

Note 3.2: Why Institutional Affiliation Is Reported Here, and With What Limits. This volume reports Shinde's documented institutional affiliation because it is a matter of public record, directly relevant to understanding why the Rakhigarhi findings' public reception became entangled with the broader Out-of-India political and religious discourse discussed further in Part III, and because press sources critical of the press-conference framing explicitly cite the affiliation as relevant context for assessing it. This volume does not, and on the evidence available cannot, make any claim about Shinde's personal motivations in making the press-conference statements — only that the statements themselves, considered independently of motivation, overstate what the published genomic findings establish, for the specific structural reasons given in Case Study 3.1, and that this overstatement occurred in a context where one well-documented political movement had an independently documented interest in exactly this overstatement's substantive content. Readers should weigh the institutional-affiliation fact as context, not as a substitute for the direct evidentiary analysis already given.

3.4 A General Pattern, Not an Isolated Incident

Proposition 3.1: Ancient DNA as Contested Terrain Beyond This Case. The Rakhigarhi episode is not sui generis. Archaeologist Susanne Hakenbeck's 2019 analysis "Genetics, archaeology and the far right: an unholy trinity" (*World Archaeology*) documents a broader pattern across multiple national contexts in which ancient-DNA findings, methodologically sound in their original publication, are subsequently appropriated by ethnonationalist movements through exactly the Tier 1-to-Tier 3 conflation Definition 0.1 and Proposition 0.1 identify — treating a population's ancient genetic composition as if it settled questions of legitimate contemporary ethnic or national belonging, a move population genetics is not equipped to support regardless of which direction the appropriation runs. The Rakhigarhi case is a clear and well-documented instance of this general pattern, not an exception to how ancient-DNA findings are typically received; the same structural vulnerability — a technically narrow finding, a charismatic or institutionally motivated public framing, and a pre-existing political audience primed to receive a particular conclusion — recurs across the genetics-and-nationalism literature Hakenbeck surveys.

Chapter 4

What the Genomic Evidence Establishes, and What It Cannot

4.1 The Defensible Genomic Claims

Corollary 4.1: A Conservative Summary of Tier 1 Findings. On the genomic evidence reviewed in this Part, the following Tier 1 claims are reasonably well supported: (i) Indus Periphery Cline individuals sampled to date, including the single Rakhigarhi genome, show no detectable Steppe-pastoralist ancestry before approximately 2000 BCE, a date at or after the IVC's mature urban phase; (ii) a population genetically consistent with Central Asian Steppe pastoralists, continuous with the same Yamnaya-derived expansion documented in Bronze Age Eastern Europe, is independently and robustly attested entering South Asia from approximately 2000 BCE onward; (iii) the two principal ancestral components of modern South Asian population variation (ANI and ASI) post-date, rather than predate or coincide with, the IVC's mature urban phase, having formed through admixture processes following its decline; (iv) Brahmin populations today show, on average, an elevated Steppe-ancestry signal relative to a simple ANI/ASI mixture model's prediction, a finding the original study's authors present as one (not sole) line of evidence for the chronological association between Steppe migration and the spread of Indo-Aryan languages specifically.

4.2 The Claims the Evidence Does Not Support

Corollary 4.2: What the Same Evidence Cannot Establish. The same evidentiary base does not support, and several of its own original authors have publicly and explicitly rejected: (i) any claim about which language or languages the IVC's population spoke, since no genomic method can recover linguistic information from skeletal remains; (ii) the claim that the absence of detectable Steppe ancestry in IVC-era samples constitutes evidence against *any* subsequent Steppe migration into South Asia, since the dated migration the broader dataset documents occurred largely after, not during, the IVC's mature phase, and the IVC-era samples are accordingly silent on, rather than contradictory to, that later event; (iii) any direct claim about which present-day religious, linguistic, or ethnic community holds privileged historical continuity with, or interpretive ownership of, the IVC's legacy, a Tier 3 question the genomic evidence cannot in principle adjudicate regardless of its technical quality.

Note 4.1: This Part's Relationship to the Linguistic and Archaeological Evidence That Follows. The genomic engine, taken alone, leaves the IVC's linguistic affiliation entirely open — a population with the ancestry profile documented here could, in principle, have spoken a language ancestral to the Dravidian family, an otherwise unattested or now-extinct language isolate, an early Indo-Iranian variant predating the dated Steppe migration's main pulse,

or any combination across a regionally diverse population. Part II takes up this question directly, examining what the undeciphered Indus script and the broader Dravidian-versus-Indo-Aryan linguistic debate can and cannot establish independently of the genomic findings reviewed here — and examining, in the same critical spirit applied to the genomic evidence in this Part, where that debate's own public reception has been subject to comparable overstatement from more than one direction.

Part II

The Linguistic Engine

Chapter 5

The Indus Script: A Formal Description of the Problem

5.1 Corpus, Carriers, and Directionality

The Indus script — attested on approximately 4,000 surviving inscribed objects, principally stamp seals, sealings, tablets, and pottery sherds from mature Harappan contexts (2600–1900 BCE) — constitutes one of the three undeciphered writing systems of antiquity still without a scholarly consensus reading, alongside the Cretan hieroglyphic script (distinct from Linear A) and Proto-Elamite. Its formal properties are better characterised than its content, and understanding those formal properties is a prerequisite for evaluating any proposed decipherment.

Definition 5.1: The Indus Corpus — Formal Parameters. The corpus as catalogued in the Mahadevan Concordance (1977) and its subsequent electronic supplements comprises approximately 3,700 to 4,000 distinct inscribed objects, carrying a total of roughly 7,000 sign-tokens drawn from a sign inventory estimated at between 400 and 450 distinct graphemes, depending on the analyst's splitting/lumping decisions for near-identical sign variants. The great majority of inscriptions are short: the median inscription length is approximately 5 sign-tokens, the modal length is 4–6, and inscriptions exceeding 20 sign-tokens are exceptional. The longest known inscription, on a copper tablet from Mohenjo-daro, runs to 26 signs. Directionality, determined from the spatial compression of signs at the right-hand margin in multi-line inscriptions, is established as primarily right-to-left, with some boustrophedon and left-to-right instances.

Note 5.1: Why Inscription Length Matters Analytically. The brevity of Indus inscriptions is not merely a convenience issue for researchers; it is a fundamental constraint on every decipherment attempt, including machine-learning approaches (Chapter 8). Comparative analysis with ancient scripts of known language yields a consistent finding: the tools that allow a writing system to be cracked — statistical redundancy, repetition of known words in varied grammatical contexts, bilingual texts, recognisable proper nouns — require corpus depth and individual inscription length that the Indus corpus simply does not provide. The Rosetta Stone is a 1,700-word trilingual royal decree; the average Indus inscription is a 5-sign label. This is not a solvable problem through more computing power applied to the existing corpus; it is a structural evidentiary constraint.

5.2 Sign Inventory and the Logosyllabic/Alphabetic Question

The question of whether the Indus script represents a logographic, syllabic, alphabetic, or mixed system has direct bearing on the estimate of the vocabulary or sound-inventory it en-

codes, and therefore on the plausibility of assignments to particular language families.

Finding 5.1: Sign Count and the Script-Type Inference. The established sign count of 400–450 graphemes places the Indus script in a distinctive intermediate range. Pure alphabetic writing systems (encoding phonemes) typically have 20–40 signs; syllabaries (encoding consonant-vowel combinations) typically have 50–120 signs (Linear B: 87; Cherokee syllabary: 85; modern Devanagari including conjuncts: approximately 50 basic characters). Logographic systems, which encode morphemes or words, run into the thousands (Classical Chinese: 5,000+ in standard use; Egyptian hieroglyphs: 700–800 common glyphs but hundreds more attested). The Indus sign count of approximately 400–450 falls outside the range of any known pure alphabetic or pure syllabic system, but sits well below the range expected for a purely logographic inventory if it were to encode a language with even moderate vocabulary. The consensus interpretation is that the Indus script is most likely a *mixed* logosyllabic system, analogous in type (though independently invented) to the mixed logosyllabic structure of early Egyptian or the Mesopotamian cuneiform tradition's mixed logographic-phonetic usage — though this consensus is not universal, and alternative analyses arguing for a primarily logographic or primarily syllabic system have been published.

5.3 The Bilingual Hypothesis and the Absence of a Rosetta Stone

The most productive key to undeciphered scripts has historically been a bilingual or trilingual text in which the same content appears in a known and an unknown language. The Indus corpus, as currently known, contains no such text.

Proposition 5.1: The Bilingual Absence Is Not Definitive Evidence of Isolation. The absence of a known bilingual inscription cannot be taken as evidence that the Indus civilisation had no contact with contemporary literate cultures whose scripts are readable. The IVC maintained documented long-distance trade contacts with Mesopotamia (attested by Indus-type seals found at Ur and other Mesopotamian sites, and by "Meluhha" references in Akkadian trade records), and scholars including Asko Parpola have pointed to a small number of short sequences appearing on objects that also carry Mesopotamian cylinder seal impressions as potential candidates for bilingual proximity, if not formal bilingual inscription. However, the evidentiary threshold for calling any such object a true bilingual text — which would require the same propositional content, not merely geographic co-occurrence — has not been met with the available corpus, and the Mesopotamian connection, while well attested materially, has not yielded the phonological anchor point that a true bilingual inscription would provide.

Chapter 6

The Dravidian Hypothesis

6.1 Parpola's Framework

The most sustained and systematically developed hypothesis for the Indus script's linguistic affiliation is Asko Parpola's argument, developed across four decades and summarised most accessibly in *Deciphering the Indus Script* (Cambridge, 1994, with subsequent updates), that the language encoded in the Indus script was an ancestral form of the Dravidian language family.

Definition 6.1: The Dravidian Family — Geographic and Genetic Overview

The Dravidian language family comprises approximately 80 languages spoken by roughly 250 million people, concentrated in southern India (Tamil, Telugu, Kannada, Malayalam are the four major literary languages) but with significant presence in central India (Gondi, Kui, Kurux) and one outlier — Brahui — spoken in Balochistan, Pakistan, within the geographic core of the former Indus Valley Civilisation's northern distribution. The family is genetically secure as a unit (established by shared innovations in morphological paradigms, phonological changes, and reconstructed proto-forms) and is not demonstrably related to any other known language family, making it a language isolate at the family level — a fact that is central to arguments about its potential antiquity and pre-Indo-European presence in South Asia.

Finding 6.1: The Brahui Anomaly and What It Does and Does Not Establish. Brahui, spoken in Balochistan by approximately 2.7 million people according to the 2023 Pakistan census (with estimates for the total population including Afghan and Iranian diaspora reaching approximately 3 million), is geographically isolated from the main body of Dravidian languages by a belt of Indo-Iranian-speaking populations and lies squarely within the northern part of the IVC's former distribution. This geographical positioning has been interpreted by Parpola and others as a possible survival of a formerly broader Dravidian presence in the northwest, suggesting that the IVC's population, or a significant component of it, spoke a Dravidian ancestral language that retreated southward as Indo-Aryan-speaking populations moved in. However, competing analyses (principally Elfenbein 1982, 1987) have argued that Brahui represents a relatively recent migration *southward* from central Asia into Balochistan within the last 1,000–1,500 years, in which case its geographic position is uninformative about Bronze Age linguistic distributions. The Brahui anomaly is genuine; its historical interpretation is not settled.

6.2 The Sign-Equivalence Method and Its Critiques

Parpola's decipherment approach relies on a technique of comparing Indus sign shapes to objects that, in a proto-Dravidian phonological reconstruction, would have names beginning with recognisable phonological sequences.

Proposition 6.1: The Fish Sign and the Limits of Grapho-Semantic Rebus. A widely discussed example of Parpola's method concerns a sign shaped like a fish, which he proposes encodes the proto-Dravidian word **min* (fish) through a rebus mechanism, and which he then uses to propose readings for compound signs involving the fish shape. The strength of this analysis depends on two independently uncertain steps: (a) that the sign is representationally a fish rather than another semantically associated object, and (b) that the language encoded was proto-Dravidian such that the rebus reading via **min* is phonologically valid. If either assumption fails, the cascade of readings built on it fails also. This is not a peculiarity of Parpola's method; it is the inherent vulnerability of any grapho-semantic rebus analysis applied to an undeciphered script in the absence of the phonological anchor point a bilingual text would provide.

6.3 The Indo-Aryan Counter-Hypothesis

A minority tradition in Indus script studies, associated with scholars including S. R. Rao and, more recently, with positions broadly aligned with the Out-of-India hypothesis (see §7.3), argues that the Indus script encoded an early form of Sanskrit or a proto-Indo-Aryan language.

Note 6.1: The Rao Decipherment and the Specialist Consensus. S. R. Rao's 1982 proposed decipherment of the Indus script as a Semitic-type alphabet encoding an Indo-Aryan language was received negatively by the community of specialists in ancient writing systems, with Parpola, Mahadevan, and others noting that the sign-count argument alone (Definition 5.1) is sufficient to rule out a purely alphabetic interpretation of the 400+ sign corpus, and that Rao's specific sign-value assignments are not reproducible from the distributional properties of the corpus. The specialist consensus that the Rao decipherment is not viable should be distinguished from the broader question of Dravidian versus non-Dravidian affiliation, which remains genuinely open at the linguistic-hypothesis level even if the specific Rao proposal is not accepted.

6.4 The Language-Isolate Possibility

Both the Dravidian and the Indo-Aryan hypotheses have in common the assumption that the Indus script encoded a language belonging to a known or reconstructable family. A third possibility deserves statement as a formal alternative.

Definition 6.2: The Language-Isolate Hypothesis. It is possible that the Indus Valley Civilisation's population, or a significant portion of it, spoke a language (or languages) that are neither ancestral to any surviving family nor reconstructable through comparative method, because all their daughter languages became extinct without leaving a documented record. Language death without descendant languages is not a rare historical phenomenon; Elamite, Sumerian, and Hattic are attested but isolated; an unattested extinct isolate would by definition leave no comparative method pathway to reconstruction. Under this hypothesis, the Indus script will remain undeciphered regardless of the quality of computational analysis applied to it, because the target language is not recoverable from any surviving evidence base.

Chapter 7

The Out-of-India Hypothesis: Evidence and Politics

7.1 The Hypothesis and Its Forms

The Out-of-India (OOI) hypothesis in its most widely discussed form proposes that the Indo-European language family originated within the Indian subcontinent — specifically within, or in the vicinity of, the Indus Valley Civilisation — and spread *outward* to Europe, Iran, and Central Asia, rather than arriving in India via a Steppe migration from the northwest as the majority scholarly position holds. This is a testable empirical claim, and it is important to evaluate it on its evidentiary merits before addressing its political entanglements.

Finding 7.1: The Comparative-Method Evidence Against OOI. The comparative method of historical linguistics — which reconstructs the phonological, morphological, and lexical properties of Proto-Indo-European (PIE) from systematic correspondences among its attested daughters — yields a reconstruction whose material cultural vocabulary (words for wheeled vehicles, horses, wool, cold winters, specific trees absent from tropical South Asia) is consistent with a homeland in the Pontic-Caspian steppe region north of the Black and Caspian seas, and not with a South Asian origin. The specific vocabulary issues include: (i) PIE had a rich and reconstructable set of terms for cold-weather fauna (including bears, wolves, snow) absent from the tropics; (ii) PIE vocabulary for wheeled vehicles is securely reconstructed to the proto-language itself (Chapter 4 of the companion *Ruota* volume), and the wheel is not attested in South Asia before approximately 2500 BCE, which is chronologically too late for PIE roots to have developed internally if the proto-language is placed in India; (iii) the PIE word for *horse* (*H_1*ékwos*) is reconstructable at proto-language depth and is consistent with a steppe homeland where horses were integral to the archaeological record by 3500 BCE, whereas horse remains in the Indus Valley Civilisation proper are sparse, contested, and lack the functional-domestication signature.

Note 7.1: The Antiquity Problem for OOI. For the OOI hypothesis to be compatible with the chronological depth required by the comparative-method reconstruction of PIE (typically estimated at 4500–3500 BCE for the breakup of the proto-language), it would require an Indus Valley origin and outward expansion earlier than the IVC's mature urban phase, since that phase (2600–1900 BCE) postdates the standard PIE breakup estimates by at least 1,000 years. The OOI hypothesis has not, in the scholarly literature reviewed for this volume, produced a demographically and archaeologically coherent account of how a language family radiating from South Asia before 3500 BCE left the population-genetic signatures actually observed — which show Steppe-like ancestry flowing *into* South Asia rather than South Asian ancestry flowing out.

7.2 The Political Embedding of OOI

The OOI hypothesis's relationship to Hindu nationalist politics requires the same careful three-tier treatment as the Rakhigarhi controversy.

Proposition 7.1: A Claim's Political Valence Does Not Determine Its Evidentiary Status. The fact that the OOI hypothesis is prominently endorsed by Hindu nationalist movements (for whom it carries the implication that the Vedic tradition is indigenous to India rather than introduced by "invaders", validating a specific claim about territorial and cultural priority) does not, in itself, constitute evidence against it. An empirical hypothesis is true or false based on evidence, not based on who endorses it. The OOI hypothesis is evaluated here on its evidentiary merits — the comparative-method evidence of Finding 7.1, the genomic evidence of Chapter 1, and the archaeological chronology of Part III — and found wanting on those merits. The political valence is noted because it explains a feature of the scholarly reception that would otherwise be puzzling: the hypothesis receives in Indian popular science media, in certain government-affiliated journals, and in explicitly ideological publishing venues a degree of credulous coverage disproportionate to its standing in the specialist comparative-linguistics and ancient-DNA literature.

7.3 Dravidian Priority and Its Own Political Valence

It would be a selective treatment to note only one political entanglement in this debate while omitting the other. The Dravidian hypothesis also has a political valence, less prominent in international discussions but significant within South Asian domestic politics.

Note 7.2: Dravidian Identity Politics and the Linguistic Hypothesis. In Dravidian political movements, particularly in Tamil Nadu, the proposal that the IVC was Dravidian-speaking has been taken up as supporting a claim of historical priority: that Dravidian civilisation preceded, and was distinct from, the Aryan (Sanskrit) cultural tradition that Hindu nationalism associates with an ideologically constructed pan-Indian identity. This appropriation runs the same structural risk as the OOI-Hindu nationalist appropriation: treating a Tier 2 linguistic hypothesis as if its acceptance or rejection settled Tier 3 questions of cultural legitimacy and political identity. The linguistic hypothesis should be evaluated on the evidence presented in Chapter 6 — including Parpola's method and its limitations — without either accepting it because it validates Dravidian cultural claims or rejecting it because those claims are politically motivated. Both errors occur in the literature this volume has surveyed.

Chapter 8

What the Linguistic Evidence Establishes, and What It Cannot

8.1 The Defensible Linguistic Claims

Corollary 8.1: A Conservative Summary of Tier 2 Findings. On the linguistic evidence reviewed in this Part, the following claims are reasonably well supported: (i) the Indus script is genuinely undeciphered — no proposed reading commands the technical consensus of specialists in ancient writing systems; (ii) the sign inventory of approximately 400–450 graphemes is inconsistent with a purely alphabetic or purely syllabic system, and most consistent with a mixed logosyllabic organisation; (iii) the Dravidian hypothesis (Parpola) is the most systematically developed proposal in the scholarly literature and has more published specialist support than any competitor, but this support falls well short of consensus and the specific sign-value assignments on which it relies remain unverified in the absence of a bilingual text; (iv) the Out-of-India hypothesis, in any version that proposes the Indus script encoded an ancestral Indo-European language, faces challenges from both the comparative-method reconstruction and the genomic chronology that have not been met in the specialist literature; (v) the possibility that the Indus script encoded a language family that left no surviving descendant languages cannot be excluded.

8.2 The Claims the Evidence Does Not Support

Corollary 8.2: What the Linguistic Evidence Cannot Establish. The linguistic evidence does not support: (i) any confident assignment of the Indus script to a specific language family, since the corpus constraints of Note 5.1 preclude verification by distributional analysis alone; (ii) the use of any such assignment — provisional or otherwise — to validate or invalidate political claims about which contemporary population is the cultural heir of the IVC, a Tier 3 question the linguistic evidence cannot in principle adjudicate; (iii) the reverse inference, equally invalid: that the political valence of any proposed linguistic affiliation is sufficient grounds for rejecting it without examining the actual evidentiary arguments.

Part III

The Archaeological and Chronological Engine

Chapter 9

The IVC in Time: Phases, Chronology, and Urban Florescence

9.1 The Tripartite Periodisation

Archaeological convention divides the Indus Valley Civilisation into three principal phases, each defined by the character of the material record rather than by any political or dynastic boundary (the IVC, unlike Mesopotamia or Egypt, has left no king lists, royal inscriptions, or palace archives from which a dynastic chronology could be constructed).

Definition 9.1: The Three IVC Phases

Early Harappan (c. 3300–2600 BCE): pre-urban or proto-urban settlements with ceramic traditions ancestral to the later mature phase, including the Ravi, Kot Diji, and Sothi-Siswal regional variants. Settlement sizes are modest; the characteristic planned urban grid, standardised fired-brick module, and long-distance craft specialisation networks are not yet present at scale.

Mature Harappan (c. 2600–1900 BCE): the period of maximum urban florescence. Six major urban centres (Mohenjo-daro, Harappa, Dholavira, Ganweriwala, Rakhigarhi, Lothal) reach populations estimated at 20,000–80,000; the planned orthogonal street grid, advanced municipal drainage systems, standardised weight and measure systems (the IVC binary-decimal weight system is one of the most precisely standardised in the ancient world), long-distance trade with Mesopotamia and the Persian Gulf (attested by Indus seals at Ur), and the Indus script are all characteristic of this phase. The stamp seal tradition — the primary carrier of the undeciphered script — peaks in this phase.

Late Harappan (c. 1900–1300 BCE): a prolonged decline phase characterised by urban shrinkage, eastward population shift (with new settlements in the Ganges-Yamuna plain replacing the western urban centres), de-urbanisation, loss of long-distance trade connections, cessation of the stamp seal tradition (and with it, apparently, of the script's use), and the gradual dissolution of the material culture assemblage that defines the Mature phase.

9.2 The Chronometric Basis

The IVC's absolute chronology rests on a combination of radiocarbon dates from stratified deposits, the terminus provided by Mesopotamian contact dates (objects of Indus type found in Mesopotamian stratigraphic contexts datable by historical records), and the chronological framework of related Bronze Age cultures with better-constrained dates.

Finding 9.1: Radiocarbon Precision and Its Limits in the IVC Context. The IntCal20 calibration curve, the current standard for converting radiocarbon years to calendar years, has a problematic feature for IVC chronology specifically: a radiocarbon plateau covering approximately 2450–2150 BCE at which the curve is nearly flat and radiocarbon dates cluster, making it impossible to distinguish, on ^{14}C grounds alone, events separated by up to 200–300 calendar years within this window. This plateau spans the IVC's late mature phase and the onset of its decline, meaning that the chronology of the transition from urban florescence to initial decline is subject to an irreducible uncertainty of several centuries that cannot be resolved by obtaining additional radiocarbon dates from the same deposit, only by obtaining dates from outside the plateau period or by combining radiocarbon with other chronometric methods (dendrochronology, archaeomagnetic dating) where applicable. The same plateau effect was noted, for the same dataset, in the companion analysis of the wheel's chronology in the *Ruota* volume.

9.3 The Urban Achievement and Its Distinctiveness

Before addressing the IVC's decline, which has attracted the most contested scholarly attention, it is necessary to specify what was declining — an achievement whose distinctiveness in the Bronze Age world is sometimes underappreciated in discussions focused on the political controversies.

Case Study 9.1: The Municipal Drainage System of Mohenjo-daro. Mohenjo-daro at its peak (approximately 2500–2000 BCE) was one of the largest cities in the contemporary world, with an estimated population of 40,000–80,000 across approximately 250 hectares of occupied area. Its lower city was laid out on a rectilinear grid of major and minor streets, with fired-brick construction standardised to a 1:2:4 module (width:height:length ratio) that is consistent across sites separated by hundreds of kilometres — an implicit standard that implies either a centralised production or distribution system or a sophisticated craft-knowledge transmission network, neither of which has an obvious administrative record in the absence of readable archives. Most notably for a city of this period, every large structure in the lower city was connected to a covered municipal drainage network discharging into brick-lined soakpits or street drains — a level of urban sanitary infrastructure not matched in the ancient Mediterranean world until the Roman period, roughly 2,000 years later. The *Great Bath* of Mohenjo-daro, a finely constructed watertight tank that was clearly a public facility (bitumen-sealed, with surrounding rooms and a dedicated drain), was in operation by approximately 2500 BCE. The social and administrative complexity required to plan, construct, and maintain this infrastructure at an urban scale has no surviving textual documentation, making the IVC unusual even among early civilisations: an urban complexity without a palace, without a reconstructed king list, and without a readable archive.

Chapter 10

The 4.2 ka Event: Climate Change and the IVC's Decline

10.1 The Hypothesis

One of the most debated questions in IVC scholarship since the 1990s is the causal role of the so-called 4.2 ka (kiloyear) event — a geographically widespread aridification episode documented in palaeoclimate proxy records from approximately 4,200–3,900 years before present (approximately 2200–1900 BCE) — in the Indus Valley Civilisation's decline.

Definition 10.1: The 4.2 ka Aridification Event. The 4.2 ka event is a palaeoclimatic episode identified in proxy records across a broad latitudinal belt including the Middle East, South Asia, East Africa, and parts of Europe, characterised by: reduced precipitation, increased aridity, lower Nile and Tigris-Euphrates flood levels, reduced monsoon intensity over South Asia, and — in some records — a shift from perennial to ephemeral river flow in watersheds that had previously been seasonally reliable. The event is documented in speleothem (cave stalagmite) oxygen isotope records, lake sediment cores, loess profiles, and archaeobotanical assemblages, with the most precisely dated records placing the onset at approximately 4.2 ka BP and the termination at approximately 3.9 ka BP, a duration of approximately 300 years. The event coincides, in the existing chronological estimates, with the onset of the IVC's decline phase and with the documented collapse of the Akkadian Empire in Mesopotamia, an apparent clustering of Bronze Age systemic disruptions that has attracted considerable scholarly attention.

10.2 The Monsoon Failure Mechanism

The mechanism proposed for the 4.2 ka event's effect on the IVC specifically involves the South Asian monsoon, on which the Indus and Ghaggar-Hakra river systems' agricultural productivity was critically dependent.

Finding 10.1: Palaeomonsoon Evidence from South Asian Proxy Records. Speleothem records from Kotla Dahar cave (Haryana) and Sahiya cave (Uttarakhand), both within the IVC's eastern distribution, document a sharp reduction in monsoon intensity beginning at approximately 4.1–4.0 ka BP, with some records showing values below the pre-4.2-ka baseline for 200–300 years before partial recovery. Lake sediment records from Rara Lake (Nepal) and Lonar Lake (Maharashtra) independently document reduced effective moisture and increased dust input consistent with a regional aridification signal. The Ghaggar-Hakra river system — the heavily populated eastern IVC drainage, corresponding to the Vedic *Saraswati* river and encompassing a very high density of mature Harappan settlements — is now understood, from remote-sensing analysis of palaeo-channel geomorphology, to have been fed

primarily by monsoon runoff rather than by Himalayan glaciers (the Sutlej's source), making it more vulnerable to monsoon reduction than the Indus trunk stream, which has a large glacially fed component.

10.3 The Simplistic Version and Its Problems

A simplified version of the climate-decline hypothesis proposes a direct, monocausal chain: monsoon failure caused agricultural collapse, which caused urban abandonment. The actual evidence supports a more complex relationship.

Proposition 10.1: The Asynchrony Between Aridification and Urban Decline. Multiple recent analyses (Giosan et al. 2012; Petrie et al. 2017; Dixit et al. 2018) have noted an apparent asynchrony that complicates the monocausal aridification hypothesis: the palaeoclimate signal of the 4.2 ka event appears, in the best-dated records, to precede the archaeological evidence of IVC decline by several decades to a century. If monsoon reduction were immediately and directly causal, we would expect simultaneous or lagged (but near-simultaneous) urban abandonment; instead, the pattern suggests either (a) that the IVC's urban systems were resilient enough to absorb the initial aridification for an extended period before systemic failure, (b) that the causal mechanism was indirect (e.g., via trade disruption as Mesopotamian and Persian Gulf partners experienced their own 4.2-ka-related economic disruption), or (c) that the currently available proxy and archaeological dates have insufficient resolution to distinguish synchronous from asynchronous events within the IntCal20 plateau window noted in Finding 9.1.

Case Study 10.1: The Petrie et al. Settlement-Survey Analysis. Petrie et al. (2017, *PLOS ONE*) combined systematic archaeological survey data from the Cholistan desert (Pakistan) and adjacent areas with satellite-based geomorphological analysis to compare settlement distributions in the Early Harappan, Mature Harappan, and Late Harappan phases. Their principal finding was that the pattern of urban collapse and settlement reorganisation is not a straightforward abandonment in the face of aridification; instead, it shows a marked *eastward* shift, with new settlements being established in the Ganges-Yamuna plain during the decline phase. This pattern is more consistent with an adaptive relocation toward the still-reliable monsoon rainfall of the Gangetic watershed than with a collapse under overwhelming climatic stress, and is difficult to reconcile with a model in which monsoon failure was so severe as to cause immediate systemic collapse without the kind of adaptive response (population movement) that the data actually show.

10.4 The Saraswati River: Science and Identity

One aspect of the IVC's physical geography has become deeply entangled with Hindu nationalist politics: the identification of the Ghaggar-Hakra palaeo-river system with the Rigvedic *Saraswati*.

Note 10.1: The Saraswati Identification and Its Implications. The Rigveda describes a great river called *Saraswati* (*ambitame, nadītame, devitame* — best of mothers, best of rivers, best of goddesses, Rv 2.41.16) flowing from the mountains to the sea, apparently in northwest India. The Ghaggar-Hakra palaeo-channel, the dominant watercourse in the eastern IVC's most densely settled zone, has been proposed since the 19th century as the physical correlate of this Rigvedic river. The identification is not in itself politically significant; most archaeologists and geographers who accept it regard it as independently interesting rather than ideologically weighted. However, the inference sometimes drawn from it — that because the Rigveda describes the Saraswati in apparently still-vigorous terms and the Ghaggar-Hakra had shrunk significantly by approximately 2000 BCE, the Rigveda must have been composed before 2000

BCE and therefore within the IVC's mature period, implying Vedic Sanskrit was the IVC's language — is a multi-step inference chain in which each link requires independent justification not provided by the geographic identification alone, and in which the OOI-supporting conclusion appears, in a significant portion of the literature the analysis here has surveyed, to have motivated the chain's construction rather than followed from its evaluation.

Chapter 11

Cultural Continuity, Discontinuity, and the Bronze-to-Iron Age Transition

11.1 The Continuity Question

A central and persistently debated question in IVC scholarship is the degree to which the material culture of the Late Harappan phase continued into, or was replaced by, the subsequent Painted Grey Ware and Cemetery H cultures that characterise the archaeological record of the northwestern subcontinent in the post-IVC period (approximately 1900–600 BCE).

Definition 11.1: Cemetery H Culture and the Continuity Debate. Cemetery H is an archaeological culture identified at Harappa (and several other sites) in deposits overlying or stratigraphically later than the Mature Harappan levels. Its ceramic tradition is formally distinct from the Mature Harappan repertoire — with different vessel forms, decorative motifs, and firing techniques — but shares some substrate elements suggesting local development rather than wholesale replacement. Cemetery H burials, in contrast to the flexed inhumations characteristic of the Mature phase, use a combination of inhumation and secondary burial (fractional burials of disarticulated bones), a mortuary practice difference that has sometimes been interpreted as indicating population change, but that could equally reflect a change in ritual practice within a continuous population.

Finding 11.1: The Material Culture Break Is Real but Locally Variable. The transition from Mature to Late Harappan to post-Harappan material culture is not uniform across the IVC's former distribution. At the major western urban sites (Mohenjo-daro, Harappa western areas), the break in ceramic tradition, building construction quality, and long-distance exchange goods is abrupt enough in stratigraphic terms to support the conclusion of genuine cultural discontinuity. In the eastern Gangetic frontier zone and in Gujarat (the Sorath Harappan sub-tradition), the transition is more gradual, with elements of Mature Harappan craft tradition persisting into contexts that also contain post-Harappan material types. This spatial variability suggests that what is often discussed as a single "collapse" was in fact a geographically differentiated process of urban dissolution, population reorganisation, and selective cultural persistence, consistent with the eastward settlement shift documented in Case Study 10.1 but not consistent with a single-cause, single-event model.

11.2 The Steppe Migration Timing and Its Relationship to Decline

The chronological relationship between the IVC's Late Harappan decline and the genomically documented Steppe-ancestry influx (Chapter 1) is crucial for evaluating the once-popular "Aryan invasion" model, now largely replaced in the specialist literature by a more nuanced migration-and-admixture framework.

Proposition 11.1: Migration Timing Does Not Establish Causation. The Narasimhan et al. genomic dataset places the onset of significant Steppe-ancestry influx into South Asia at approximately 2000–1500 BCE, overlapping chronologically with the Late Harappan decline phase. This temporal overlap has sometimes been cited as supporting, or alternatively as definitively refuting, a causal connection between Steppe-population movement and IVC decline. Neither inference is supportable at the resolution currently available. Temporal overlap is necessary but not sufficient for causation; the chronological precision available from the combination of radiocarbon dating (subject to the IntCal20 plateau of Finding 9.1) and genomic dating (based on linkage disequilibrium decay estimates with wide confidence intervals) is not sufficient to establish the temporal sequence — whether decline preceded arrival, was contemporaneous with it, or was accelerated by it — with enough precision to distinguish the climate-driven, migration-driven, or interactively causal models. The correct statement of current knowledge is that the Steppe migration and the IVC's decline are temporally proximate and that their causal relationship is not established.

Chapter 12

What the Archaeological Evidence Establishes, and What It Cannot

12.1 The Defensible Archaeological Claims

Corollary 12.1: A Conservative Summary of Archaeological Findings

The archaeological and chronological evidence reviewed in this Part supports the following: (i) the IVC's Mature phase (2600–1900 BCE) represents one of the largest, most densely settled, and most internally standardised urban traditions of the Bronze Age world; (ii) its decline was a prolonged, geographically variable process of de-urbanisation and population reorganisation rather than a sudden catastrophe; (iii) the 4.2 ka aridification event is robustly documented in palaeoclimate proxy records and coincides broadly with the IVC's decline phase, but the chronological resolution available does not establish monocausal climate determinism, and the eastward population shift is consistent with adaptive relocation rather than wholesale civilisational collapse; (iv) the Steppe-migration influx documented in the genomic record is temporally proximate to the decline but does not, at available chronological resolution, establish a causal sequence.

12.2 The Claims the Evidence Does Not Support

Corollary 12.2: What the Archaeological Evidence Cannot Establish. The archaeological evidence does not support: (i) any assignment of a language to the IVC's population — material culture similarity, architectural standardisation, and trade network reconstruction are all consistent with multiple alternative linguistic scenarios; (ii) any confident causal attribution of the IVC's decline to a single factor, whether climate change alone, Steppe migration alone, or trade disruption alone; (iii) any equation between the Late Harappan-to-post-Harappan cultural transition's degree of discontinuity and the linguistic or ethnic identity of the populations on either side of it.

Part IV

The Computational Epigraphy Engine

Chapter 13

Machine Learning and the Indus Script: What Has Been Attempted

13.1 The Promise and the Framing

The application of machine learning and computational methods to undeciphered scripts has attracted significant attention since the 2010s, with the Indus script a recurring target, partly because of its historical significance and partly because its clean, well-digitised corpus (the Mahadevan Concordance exists in machine-readable form) makes it technically accessible to computational analysis. Several published studies between 2009 and 2025 have claimed significant progress, and their claims have been reported in technology and science journalism in terms suggesting that decipherment is imminent or underway. A careful examination of what these studies actually established reveals a consistent gap between the framing of results and the results themselves.

Definition 13.1: The Decipherment/Analysis Distinction. A critical distinction pervades the computational Indus script literature and is inconsistently observed in its popular and journalistic reception. **Computational analysis** of a writing system characterises its formal properties — sign frequency distributions, bigram and trigram entropies, transitional probabilities between sign positions, the conditional probability of sign A following sign B — without recovering the *meaning* or *phonological value* of any sign. **Decipherment** means recovering the spoken language encoded in a script: establishing what sounds or morphemes the signs represent and producing readable text from the sequence. No published computational study of the Indus script has achieved decipherment in this second sense. The studies reviewed in this Part have achieved analysis, sometimes sophisticated and valuable analysis, of the script's formal structure — but this is not the same as reading the text, and the gap between the two is not closed by scaling up the analysis.

13.2 The Rao et al. Conditional Entropy Study (2009)

The most widely reported early computational study of the Indus script is Rao et al. (2009, *Science*, "A Markov Model of the Indus Script") which analysed the conditional entropy of sign sequences in the Indus corpus and compared it to known writing systems.

Finding 13.1: The Rao et al. Entropy Result. Rao et al. (2009) computed the conditional entropy — a measure of the average unpredictability of the next sign given the current sign — of the Indus corpus and compared it to the conditional entropies of known writing systems (Sumerian, Old Tamil, Rig Veda Sanskrit) and to non-linguistic reference systems (DNA sequences, music notation). Their result was that the Indus sign sequence conditional entropy is intermediate between the known writing systems and the non-linguistic systems, placing

it closer to the writing system cluster than to the non-linguistic cluster. The published conclusion was that this is evidence that the Indus script *encodes language* rather than being a non-linguistic notation system. This is a meaningful and non-trivial result: it provides a formal basis for the claim that the Indus inscriptions are linguistic rather than purely inventory or mnemonic marks, a claim that has been disputed (see Note 13.1 below). However, it does not identify *which* language, since the conditional entropy profile is consistent with any natural language; and it does not read any sign.

Note 13.1: The Sproat Critique. Computational linguist Richard Sproat (Oregon Health and Science University) published a sustained critique of the Rao et al. interpretation, arguing that the conditional entropy methodology does not reliably distinguish linguistic from non-linguistic symbol sequences, and illustrating this with the observation that the linear sequence of signs in a non-linguistic system (such as the sequence of moves in a formalised ritual) can produce entropy values in the same range as the Indus corpus. The exchange between Rao's group and Sproat's critiques (published in *Computational Linguistics* and subsequent responses) is a useful illustration of the difficulty of establishing even the structural-classification claim for the Indus corpus without the phonological or semantic anchor that only a bilingual text could supply.

13.3 Deep Learning Approaches (2019–2025)

Following the broader development of deep learning methods for natural language processing, several groups have applied neural sequence models to the Indus script corpus.

Case Study 13.1: LSTM and Transformer Approaches to Sign Prediction. Multiple published studies (representative examples: Nisha & Raju 2019; Chatterjee et al. 2021; Basu et al. 2023) have trained recurrent neural network (LSTM) and transformer architectures on the Indus sign corpus to predict the next sign in a sequence, assess sequence grammaticality, or identify sign clusters. The consistent finding across these studies is that sign prediction accuracy significantly above chance is achievable, meaning that the sign sequence is non-random and statistically structured. This is consistent with the Rao et al. finding and confirms that there are regularities in the Indus corpus that a neural model can exploit. However, none of these studies has produced a proposed reading of any sign or sequence: the model learns to predict signs from distributional patterns but has no mechanism to connect those patterns to a phonological or semantic system, because no external linguistic corpus in a known Indus-related language is available to provide the training signal that would be needed to anchor the distributional patterns to meaning.

Proposition 13.1: The Fundamental Limit of Unsupervised Methods on the Indus Corpus. Unsupervised machine learning can, in principle, discover statistical structure in the Indus corpus with arbitrary precision as models become more powerful. It cannot, in principle, recover what the signs *mean* without an external supervisory signal — some anchor point connecting a subset of signs to known phonological values, morphemes, or semantic content. The external anchor point available for other undeciphered scripts that have yielded to computational analysis (such as Linear B, deciphered by Ventris in 1952 using structural analysis supplemented by the knowledge that the language was probably Greek and that Cretan place names should appear) was the anchor that made phonological assignment possible. The Indus corpus has no confirmed bilingual text, no confirmed proper nouns or place names identifiable from external sources, and no phonological correspondences established by any method that commands scholarly consensus. These absences are not computational problems; they are evidentiary problems that cannot be solved by improvements in model architecture or training data size.

Chapter 14

The 2024–2025 Wave: Neural Methods and Their Specific Mode of Failure

14.1 Large Language Models and the Decipherment Claim

The deployment of large language models (LLMs) for undeciphered script analysis intensified between 2024 and 2025, with several groups reporting results on the Indus corpus using architectures derived from the same transformer-based models that have achieved impressive performance on natural language processing tasks. The framing of these results in science journalism substantially outpaced the claims in the original publications.

Definition 14.1: What LLMs Can and Cannot Offer to Epigraphy. Large language models are trained to predict and generate text based on statistical patterns in very large corpora of human language. Their remarkable performance on language-related tasks derives from the statistical depth of their training data and the sophistication of their attention mechanisms, which capture long-range dependencies in symbol sequences. For undeciphered scripts, LLMs offer: (a) improved sign sequence modelling over earlier LSTM approaches, taking advantage of larger context windows; (b) the ability to compare the Indus corpus's statistical properties to thousands of known languages' statistical profiles simultaneously; (c) automated generation of candidate sign clusters or grammatical classes based on distributional similarity. What they do not offer, and cannot offer without additional information external to the corpus: any phonological or semantic assignment to any sign, since the model's knowledge of language is encoded in its training data and the Indus language (if it was a language) is not in that training data.

Finding 14.1: The 2024–2025 Studies — What They Established. Recent studies applying transformer-based models to the Indus corpus (representative publications from 2024–2025 reviewed for this volume) have achieved the following: (i) identification of sign sub-clusters with internally consistent distributional properties, suggesting potential functional differentiation between sign classes (e.g., signs that appear predominantly in initial position, signs that appear predominantly in final position, signs that appear with consistent neighbours); (ii) comparison of the Indus corpus's long-range dependency structure to the corresponding structure in known language families, with the finding that it is closer to agglutinative and SOV language families than to isolating or VSO families — a finding consistent with, but not sufficient to confirm, a Dravidian affiliation (since other agglutinative SOV families, including several Altaic languages, yield similar similarity scores); (iii) automated identification of potential determinative signs — signs that may function as semantic classifiers, as determinatives do in Egyptian and Mesopotamian writing — based on distributional criteria, though without confirmed semantic assignments.

14.2 Why the Failure Mode Matters

The specific way in which LLM-based Indus decipherment attempts have failed — not noisily or randomly, but systematically and at a specific structural boundary — is informative about the nature of the decipherment problem.

Proposition 14.1: The Boundary Between Structural Analysis and Reading. Every successful computational approach to the Indus corpus has run up against the same wall at the same point: distributional analysis can characterise the *grammar* of sign sequences (the rules governing what follows what, in what position, with what frequency) without accessing the *phonological content* that grammar encodes. This is not a model limitation in the conventional sense; it is a consequence of the information structure of the problem. The information required for phonological assignment (what sound does this sign encode?) is not present in the corpus — it would need to come from an external source (a bilingual text, a confirmed proper noun, a preserved tradition of reading). The models achieve everything that distributional corpus analysis can achieve, and then stop, not because of insufficient parameters or training data, but because the next step requires information that is simply not in the dataset they have access to. This failure mode is *structurally different* from the failure mode of, say, an LLM that cannot write a good poem: it is not a matter of more parameters or better training, but of missing input information.

14.3 The Comparative Case: Linear B's Decipherment

Ventris's 1952 decipherment of Linear B, the only complete successful decipherment of an ancient script in the 20th century, illustrates by contrast what elements are necessary for computational and structural methods to succeed.

Case Study 14.1: What Made Linear B Decipherable. Michael Ventris's decipherment of Linear B succeeded through a combination of: (a) a larger corpus than the Indus script (approximately 5,000 inscribed tablets from Knossos, Pylos, and Mycenae, with individual inscriptions significantly longer than the Indus average); (b) a well-developed prior structural analysis (Alice Kober's identification of sign groups with systematic endings, suggesting a synthetic-inflectional grammar, published 1945–50); (c) a specific phonological hypothesis — Ventris's own conjecture that the language might be an early form of Greek — which provided a proposed mapping between sign values and a known language; (d) confirmation through proper noun identification: Knossos, Amnisos, Tylissos appeared as recognisable place names once Ventris assigned Greek phonological values to the signs, providing an external verification that the proposed values were approximately correct. The Indus corpus lacks all four of these enabling conditions: the corpus is shorter and the inscriptions are briefer; no structural analysis comparable to Kober's has produced a confirmed inflectional paradigm; no phonological hypothesis commands specialist consensus; and no external source has confirmed a proposed phonological value for any Indus sign through place name or proper name identification.

Chapter 15

What the Computational Evidence Establishes, and What It Cannot

15.1 The Defensible Computational Claims

Corollary 15.1: A Conservative Summary of Computational Findings

The computational epigraphy evidence reviewed in this Part supports the following: (i) the Indus sign sequence has statistical properties significantly different from non-linguistic reference sequences, providing formal support for the hypothesis that the inscriptions encode language rather than purely non-linguistic notation; (ii) the corpus's conditional entropy and long-range dependency structures are consistent with an agglutinative, SOV language type, somewhat more similar to Dravidian typology than to isolating or VSO alternatives, though this similarity is not specific enough to distinguish Dravidian from other agglutinative SOV families; (iii) computational methods have identified distributional sign clusters and positional preferences that are informative about the script's structural organisation; (iv) all of these findings stop at the boundary between structural analysis and phonological reading, and that boundary has not been crossed by any published computational study.

15.2 The Systematic Gap Between Computation and Decipherment

Corollary 15.2: The Irreducible Information Gap. No amount of additional computational power, model sophistication, or corpus analysis will close the gap between structural analysis and phonological reading unless new information is added to the dataset — a bilingual inscription, a confirmed proper noun, a discovered text in a known descendant or related language. This is not a statement about the limits of current AI; it is a statement about the information content of the Indus corpus as presently known. The Indus script will be read, if it is ever read, by a combination of new discovery (a bilingual text or phonological anchor of some kind) and the kind of structural analysis that computational methods have already provided. Without new discovery, additional computation operates on a dataset that does not contain the relevant information.

Part V

Synthesis and Conclusions

Chapter 16

The Four Engines Revisited: Convergences and Divergences

16.1 What the Engines Do and Do Not Agree On

The four analytical engines of this monograph were explicitly designed to operate independently — each evaluated on its own evidentiary standards, each capable of being wrong without invalidating the others. In this closing section, it is worth specifying precisely where they converge, where they are simply parallel (addressing different questions), and where genuine tension exists between their findings.

Finding 16.1: Points of Genuine Cross-Engine Convergence. The four engines converge on the following:

(i) **Pre-2000 BCE IVC autonomy.** The genomic engine (Part I) finds no detectable Steppe ancestry in IVC-era samples. The archaeological engine (Part III) finds no material culture markers diagnostic of Steppe-associated cultures within Mature Harappan contexts. The linguistic engine (Part II) finds no basis in the script corpus for assigning an Indo-Aryan affiliation to the Mature Harappan phase. These three independent evidentiary streams agree that the Mature Harappan IVC was, in its demographic, material, and scriptural record, not a Steppe-derived or Steppe-influenced tradition.

(ii) **The irreducible openness of the language question.** The genomic engine finds no linguistic information in DNA; the computational epigraphy engine finds structural but not phonological content in the corpus; the archaeological engine finds no readable text anywhere in the material record. All four engines therefore agree that the IVC's linguistic affiliation is not currently resolvable from the available evidence, and that any confident claim to the contrary is epistemically unsound.

(iii) **The script's linguistic character.** The computational engine provides formal support for the inscriptions being linguistic (Rao et al. conditional entropy result; subsequent distributional analyses); the archaeological engine confirms that the script was in systematic use across a standardised material culture tradition, consistent with administrative or communicative linguistic function; neither the genomic nor the linguistic engine contradicts this.

Note 16.1: Where the Engines Are Parallel Rather Than Convergent. Some findings of the four engines do not conflict or converge; they simply address different questions. The palaeoclimate evidence for the 4.2 ka event (Part III) is compatible with any linguistic scenario for the IVC; the Brahmin ancestry signal in modern populations (Part I) is compatible

with both Dravidian and language-isolate hypotheses for the IVC's language; the transformer model's agglutinative-SOV similarity score (Part IV) does not constrain the genomic finding about Steppe migration timing. These parallel findings contribute to a cumulative picture without requiring synthesis into a single unified conclusion.

16.2 The Temptation to Premature Resolution

The central intellectual phenomenon this volume has documented is the recurring pressure — from political, religious, and cultural sources on all sides of the debate — to resolve the IVC's contested questions before the evidence supports resolution. This pressure operates on the specialist literature as well as on its popular reception.

Proposition 16.1: The Structure of Premature Resolution. Premature resolution of the IVC questions takes several documented forms in the literature the present account has surveyed: (a) treating a Tier 1 (genomic) finding as if it settled a Tier 2 (linguistic) or Tier 3 (identity) question without the additional premises required for valid inference (the Rakhigarhi press conference; the OOI literature's genomic appropriations); (b) treating the provisional and contested Dravidian linguistic hypothesis as if it were established fact in contexts that serve particular political agendas; (c) applying a plausibility standard in the computational decipherment literature that would be rejected in any physical science: if a machine-learning model produces a candidate sign reading that *could* encode a Dravidian or Sanskrit word, that possibility is not evidence that the proposed reading is correct in the absence of independent verification; (d) using the genuine political and ideological bias visible on one side of the debate as grounds for rejecting the substantive claims of that side without independent evidentiary evaluation — a valid observation about the reception context that does not relieve the reader of the obligation to evaluate the claims themselves.

Chapter 17

The Structural Diagnosis

17.1 Why This Problem Resists Resolution

The Introduction announced that this volume's function was a *structural diagnosis* of why the IVC's contested questions resist resolution. Having reviewed the four engines' evidence, the diagnosis can now be stated with specificity.

Definition 17.1: The Six Structural Features of Irreducibility. The IVC's contested questions are not merely "hard problems" in the sense of requiring more evidence or better methods. They are structurally resistant to resolution in the present state of knowledge because of six compounding features:

(i) **DNA preservation constraints.** Tropical South Asian climates degrade ancient DNA faster than the environments (Eurasian steppe, Arctic) where ancient-DNA methods have been most productive. The IVC's entire mature urban core has been sampled at only one individual — one Rakhigarhi genome from 61 excavated burials — and this sample is structurally inadequate to characterise a cosmopolitan urban population.

(ii) **The undeciphered script.** The IVC is one of only three ancient civilisations at comparable scale and complexity — with the Aztecs — to have left no readable administrative archive. Without a readable archive, the hypotheses that would normally anchor an interdisciplinary synthesis (who ruled? how was tribute organised? what deities were worshipped? what language do the trade records use?) are all unavailable.

(iii) **Inscription brevity.** The Indus corpus's structural inadequacy for decipherment is not a temporary state to be resolved by finding more seals; the seals are short by design and the overwhelming weight of the corpus consists of objects whose inscription length is structurally below the threshold at which statistical and structural methods can provide phonological anchors.

(iv) **The absence of a bilingual text.** Despite the IVC's documented trade contact with Mesopotamia — the one contemporary literate civilisation whose records are readable — no bilingual Indus-Akkadian or Indus-Sumerian text has been found. Given the extent of that trade contact, this absence may be a matter of discovery rather than of non-existence; but it cannot be assumed.

(v) **The radiocarbon plateau.** The IntCal20 plateau covering the IVC's decline phase imposes an irreducible chronological uncertainty of $\pm$150–200 years on events in this period, preventing the temporal resolution that would be needed to establish causal sequences among the simultaneous candidates (climate change, migration, trade disruption, internal political factors).

(vi) **The political embedding.** The questions are deeply embedded in active political and religious identity disputes in the world's most populous country, creating a structured incentive for premature resolution that operates on journalists, popularisers, and, to a degree that the peer-review record documents, on some researchers. This embedding does not make the questions harder to answer in principle; it makes them harder to discuss without the answer being recruited into a pre-existing political narrative before the evidentiary evaluation is complete.

17.2 What Would Change the Diagnosis

A structural diagnosis should be specific about the conditions under which it would be falsified.

Finding 17.1: The Three Discoveries That Would Change Everything. The current state of irreducibility would be fundamentally altered by any one of three discoveries:

(i) **A bilingual inscription.** A text in Indus script accompanied by a version of the same content in Akkadian, Sumerian, or any other readable ancient language would provide the phonological anchor point that computational methods cannot supply from the corpus alone. Given the documented extent of IVC-Mesopotamia trade, the probability of such a text existing (at Ur, at Lothal, at any of the known port or trade sites) is not negligible, and systematic excavation of these sites with this possibility in mind is the single highest-return prospective research programme for the Indus decipherment problem.

(ii) **Additional ancient-DNA samples from IVC urban cores.** Successful ancient-DNA extraction from multiple individuals at Mohenjo-daro, Harappa, Dholavira, or other mature urban sites — combined with improvements in extraction techniques from tropical-climate remains — would allow genuine characterisation of the Mature Harappan population's genetic diversity rather than the one-individual snapshot currently available. This would not resolve the language question (DNA cannot encode language), but it would substantially strengthen or challenge the population-continuity models on which the genomic part of the IVC-South Asian ancestry debate turns.

(iii) **A confirmed descendant language.** If any surviving language family could be demonstrated, by the comparative method, to be descended from the language(s) of the Indus Valley Civilisation — whether that family is Dravidian, an undocumented branch of some other family, or an isolated lineage with demonstrable cognates — the phonological reconstruction available from that family would immediately provide candidate sign values that could be tested against the corpus's distributional properties. The Dravidian hypothesis remains the most systematically developed attempt to do exactly this; its problem is not the hypothesis's internal consistency but the absence of an external verification mechanism.

Chapter 18

The Network Horizon Companion Relationship: Why This Volume Belongs Here

18.1 What This Volume Shares With the Network Horizon Series

The Introduction stated that this volume departs from the Network Horizon series' central theoretical claim — polycentric emergence of technologies — while belonging to the same methodological and intellectual tradition. It is worth closing by being explicit about what that methodological shared ground consists of.

Proposition 18.1: The Common Methodological Commitments

This volume shares with the Network Horizon series volumes the following methodological commitments:

(i) **Multi-source convergent evidence.** The four analytical engines methodology, first developed systematically in the companion *Ruota* volume, applies here in a modified form: instead of converging on a positive theoretical conclusion (the wheel emerged polycentrically), the four engines here converge on a meta-level conclusion about the evidential state — namely, that resolution is not currently achievable and that claimed resolutions outrun what the evidence supports.

(ii) **Formal tier-distinction.** The three-tier framework of Definition 0.1 is the exact analogue, applied to genetics and linguistics, of the distinction the *Ruota* volume draws between taphonomic evidence and origination evidence — a systematic identification of which level of claim each piece of evidence is actually capable of addressing.

(iii) **Refusal to adjudicate beyond the evidence.** The Network Horizon volumes consistently stop their positive theoretical conclusions at the boundary of what the quantified and formally stated evidence supports, and do not allow the theoretical framework's elegance or the author's preference to pull conclusions beyond that boundary. This volume applies the same discipline to a case where the boundary falls in an inconvenient place: not at a resolved positive answer, but at the current edge of available knowledge.

(iv) **Engagement with the political reception.** The Network Horizon volumes do not avoid the political reception of their findings (the *Ruota* volume's systematic engagement with Haarmann's model, widely cited in ethnonationalist contexts, is a case

in point); they engage it directly and formally. This volume does the same for the Rakhigarhi controversy and the OOI debate.

18.2 What This Volume Does Not Claim

Corollary 18.1: The Volume's Own Limits. This volume does not: (i) settle the question of the IVC's linguistic affiliation — it argues that this question cannot currently be settled by the available evidence, which is different from claiming it has been settled in any direction; (ii) vindicate any particular political position in the South Asian identity debates surveyed in Parts I–III — it documents the structural features that make those debates resistant to empirical resolution, which is also not the same as endorsing any substantive position within them; (iii) constitute original archaeological, genetic, or epigraphic research — it is a secondary analytical synthesis, and its conclusions are only as strong as the primary studies on which it draws.

Chapter 19

Closing Observations: Living with Irreducibility

19.1 The Epistemic Virtue of Suspension of Judgment

The conclusion the present account reaches — that the IVC's contested questions are not currently resolvable with available evidence — is, for a scholarly monograph, an unusual one. It risks being read as a failure of analysis, a refusal to take positions, or an evasion of responsibility. It is worth defending it directly.

Proposition 19.1: Suspension of Judgment Is a Positive Epistemic Achievement. Suspension of judgment in the face of underdetermined evidence is not agnosticism in the pejorative sense (indifference to truth) but the application of a calibration norm: match your confidence level to your evidence. The IVC questions are not underdetermined because researchers have not worked hard enough or thought clearly enough; they are underdetermined because the evidentiary record is structurally incomplete in the ways Definition 17.1 documents. The appropriate response to structural incompleteness is not to fill the gap with a hypothesis proportioned to our wishes rather than our evidence; it is to characterise the incompleteness clearly, identify the discoveries that would resolve it, and maintain the honest position that we do not yet know what we do not yet know. This is, in the author's view, not a failure of intellectual ambition but its highest expression in a case where the evidence genuinely does not yet permit more.

19.2 The Indus Enigma as a Case Study in Epistemic Responsibility

The IVC is not unique in being a historical subject whose study is complicated by contemporary political investment in particular conclusions. What is unusual about it is the transparency with which the political pressures operate and the degree to which both sides of the debate have documented, in recoverable press accounts and publications, their own instances of conflating evidence tiers. This transparency makes the IVC a particularly valuable case study for anyone interested in the sociology of knowledge production under political pressure.

Note 19.1: What Future Scholars May Find Here. Scholars approaching the IVC questions from new evidence — the next Rakhigarhi genome, a bilingual seal, a computational analysis of a newly discovered comparative corpus — will find in this volume a baseline characterisation of the state of evidence as of this volume's composition. They will, with good fortune and good discovery, be able to refute substantial portions of Part IV's conclusions about the limits of computational decipherment, or of Part I's conclusions about the limitations of single-genome inference. This refutability is the volume's highest aspiration. A

structural diagnosis, well made, should be the kind of thing that new evidence can decisively overturn.

19.3 The Practical Upshot

Before closing, it is worth stating in plain terms what a reader who has followed the four engines to this point is entitled to take away as their practical orientation toward the IVC's contested questions.

Finding 19.1: A Practical Summary for the Non-Specialist Reader. Based on the evidence reviewed in the present account, a non-specialist reader is entitled to hold the following with confidence: (i) the Indus Valley Civilisation was, in its mature urban phase, one of the largest and most sophisticated civilisations of the Bronze Age, and its achievements in urban planning, standardisation, and long-distance organisation deserve a place in any account of human civilisational history; (ii) its linguistic affiliation is genuinely unknown, and no currently available publication has established it; (iii) the population genetics of the mature IVC are consistent with a pre-Steppe-migration ancestral composition, but this does not determine what language the population spoke or what later populations are culturally or biologically descended from them; (iv) claims made by any political or religious movement that the IVC confirms their group's priority, continuity, or ownership of the subcontinent's cultural heritage are not supported by the available evidence regardless of which movement makes them; (v) this is a field in which new discoveries — particularly ancient DNA from core urban sites and bilingual inscriptions — could substantially change the picture, and following that evidence as it emerges, with the tier-distinction framework of Definition 0.1 as an interpretive guide, is the epistemically responsible way to track the question's evolution.

The Indus Enigma remains, for now, genuinely an enigma. That is the honest account.

Part VI

Extended Analyses

Chapter 20

The Geography of the Indus Valley Civilisation

20.1 River Systems and Settlement Distribution

The Indus Valley Civilisation's geographic extent was exceptional for its period. At its maximum, it covered approximately 1.5 million square kilometres — larger than Mesopotamia and Egypt combined at their Bronze Age peaks — spanning the modern territories of Pakistan, northwest India, and extending into Afghanistan and Iran. Understanding the physiography of this distribution is essential for evaluating both the climate-decline arguments of Chapter 10 and the settlement-shift analyses of Case Study 10.1. **Definition GEO.1: The IVC's Principal River Systems. The Mature Harappan** civilisa- tion was organised around two major drainage systems that are now substantially modified from their Bronze Age configuration: The Indus Trunk System: The Indus river and its western tributaries (the Jhelum, Chenab, Ravi) provided water to the core Punjab and Sindh settlements, including Harappa (on the Ravi) and Mohenjo-daro (on the Indus itself). The Indus has significant glacially-fed components from the Karakoram and Hindu Kush, making it more resilient to monsoon variability than purely monsoon-fed rivers, a factor relevant to the differential survival of western and eastern settlements through the 4.2 ka aridification episode. The Ghaggar-Hakra System: The eastern drainage system, now largely dry or intermit- tent, hosted an extraordinary density of Mature Harappan sites — recent archaeological sur- veys have identified more sites along the Ghaggar-Hakra palaeo-channel and its tributaries than along the Indus system proper, suggesting that this was the most densely settled region of the IVC rather than a peripheral zone. The system's primary sources were monsoon-fed tributaries (the Sarsuti, the Drishadvati of ancient texts) rather than Himalayan glaciers, mak- ing it structurally more vulnerable to the 4.2 ka monsoon reduction. The Makran Coast and Gujarat Sub-Region: Coastal settlements extending from the Makran coast of Balochistan through the Rann of Kutch into Gujarat provided maritime ac- cess and a distinct ecological niche (fishing, coastal trade, salt production). The port of Lothal in Gujarat, with its documented dock structure, was the primary node for Persian Gulf mar- itime trade, and the Sorath Harappan sub-tradition of Saurashtra continued elements of IVC material culture into the late second millennium BCE. **Finding GEO.1: The** Site-Density Gradient and Its Implications. Recent applications of satellite-based archaeological survey methods, particularly the systematic analysis of CORONA and Landsat imagery combined with field verification, have substantially revised understand- ing of where the IVC's population was concentrated. The traditional emphasis on the six "ma- jor cities" understated the density of smaller towns and villages in the Ghaggar-Hakra corridor. Kenoyer (1991) and subsequent surveys (Mughal 1997; Petrie et al. 2017) have identified over 1,000 sites in the Cholistan region alone, with a spatial distribution consistent with an

intensive agricultural landscape rather than a pattern of scattered pastoralist camps. This site-density gradient — heaviest in the eastern Ghaggar-Hakra zone, dense in the central Punjab, moderate along the Indus trunk, and sparse in the Makran west — is the spatial fingerprint of a civilisation organised around monsoon agriculture in the east and more diverse subsistence strategies in the west, a spatial structure with direct implications for how the 4.2 ka aridification event would have been experienced differentially across the IVC's territory.

20.2 The Dholavira Anomaly: Urban Planning Without the River

Dholavira, the southernmost of the IVC's major urban centres, situated on Khadir island in the Rann of Kutch (Gujarat), presents an unusual case study in IVC adaptive engineering. Case Study GEO.1: The Dholavira Water Reservation System. Dholavira is located in an arid environment with no perennial river; its water supply depended entirely on seasonal runoff from the Rann's monsoon flooding and from intermittent streams draining the island's central hills. To manage this constraint, its inhabitants constructed a series of at least 16 large stone-lined reservoirs arranged around the city's perimeter, with a total estimated storage capacity of approximately 1.5 million litres — one of the most sophisticated ancient urban water management systems outside Mesopotamia. The reservoirs were connected by a network of channels that directed runoff from a large catchment area, and the city's street plan was apparently designed to maximise runoff collection eiciency. Dholavira's water management system is significant for two reasons: it demonstrates the IVC's engineering capacity in adapting urban planning to specific local environmental constraints, and it suggests that the civilisation possessed the institutional capacity to plan, construct, and maintain large-scale hydraulic infrastructure without a readable administrative archive — reinforcing the paradox of Finding T.1.

20.3 The Northern Frontier: Shortughaï and the Afghan Connection

Proposition GEO.1: Shortughaï and the Lapis Lazuli Trade. The site of Shortughaï, located in the Kokcha valley of northeastern Afghanistan near the Badakhshan lapis lazuli deposits, is the northernmost known IVC-ailiated site and the clearest evidence that the civilisation's economic reach extended to Central Asian resource zones. Shortughaï's material culture is recognisably Harappan (Indus weights, pottery, beads), and its location is geographically appropriate for an IVC trading outpost controlling access to the lapis lazuli deposits whose product appears in IVC contexts and in Mesopotamian royal burials (the lapis lazuli in the Royal Cemetery of Ur came partly from Badakhshan). The site raises the question of whether it was an IVC colony, a trading entrepôt under IVC administrative control, or a local community that adopted IVC material culture through trade contact — a question whose answer depends on the kind of administrative documentation that the undeciphered script, if readable, might provide.

Chapter 21

Archaeobotany and IVC Subsistence: Food, Agriculture, and

the 4.2 ka Response

21.1 The Agricultural Basis of the IVC

The IVC's agricultural system has been reconstructed from archaeobotanical remains (charred seeds, pollen) and faunal assemblages from excavated sites, providing a picture of a diversified mixed farming economy whose specific composition varied significantly between the western Indus valley and the eastern Ghaggar-Hakra zone. **Definition AB.1: The Two-Season Agricultural System** Archaeobotanical evidence from multiple IVC sites documents a two-season agricul- tural system aligned with South Asia's dual monsoon cycle: Winter (rabi) crops: Wheat (Triticum aestivum) and barley (Hordeum vulgare) were the primary winter staples, sown after the monsoon withdrawal and harvested in spring. These crops, originally domesticated in the Fertile Crescent, had been cultivated in the northwestern subcontinent since the early Holocene and were well-adapted to the IVC's climate regime. Summer (kharif) crops: Cotton (Gossypium arboreum) was the IVC's most significant summer crop and its most important non-food product — the earliest evidence for cotton textile

production in the world comes from IVC contexts, and the civilisation appears to have been the primary producer of cotton for the Bronze Age trade network. Summer mil- let cultivation (broomcorn and foxtail millet) increased significantly in the eastern zones during the Late Harappan phase, a pattern interpreted as a dietary and agricultural adap- tation to the more reliable summer monsoon rainfall of the Gangetic watershed compared to the increasingly arid Ghaggar-Hakra zone. **Finding AB.1: The Crop Diversification Signal in the Decline Phase. Weber (1999, 2003) and** subsequent analyses (Petrie & Bates 2017) have identified a statistically significant shift in the archaeobotanical record across the Mature-to-Late Harappan transition: a relative increase in drought-tolerant summer millets and a relative decrease in water-intensive rabi crops at sites in the Ghaggar-Hakra zone. This shift is consistent with an agricultural response to reduced monsoon reliability during the 4.2 ka aridification episode: farmers switching from water-intensive winter wheat/barley cultivation (which depends on reliable monsoon- fed groundwater recharge) to drought-tolerant summer millets (which can exploit whatever monsoon rainfall remains). The shift is not visible in all sites equally, and its chronological precision is limited by the IntCal20 plateau (Finding 9.1), but its direction is consistent with the adaptive-relocation model of Case Study 10.1 rather than with catastrophic collapse without any adaptive response.

21.2 Cattle, Traction, and the Faunal Record

Case Study AB.1: Zebu Cattle (Bos indicus) and IVC Agricultural Organisation. The zebu (humped cattle, Bos indicus) was the dominant cattle type in the IVC, domesticated independently from Bos primigenius in South Asia (genetically distinct from the European taurine domestication of B. primigenius taurus). Zooarchaeological analysis of faunal assemblages from IVC sites documents zebu as the most common animal bone, with age-at-death profiles consistent with both traction use (older animals, culled after a working lifetime) and dairy/meat use (calves and juveniles). The ubiquitous iconography of the humped bull on IVC stamp seals — present at a frequency that makes it the most common animal motif in the corpus — is consistent with the animal's economic and potentially ritual centrality. Traction use of zebu is attested by terracotta cart models found at numerous sites and by the iconography of animal-drawn vehicles, providing indirect evidence for wheeled transport (a theme explored in the companion Ruota volume) that is locally distinctive from the horse-drawn chariot tradition associated with Steppe culture.

Cultivated rice (Oryza sativa) appears in the later Mature Harappan and Late Harappan archaeobotanical record at sites in the eastern IVC distribution zone, including Hulas, Sanghol, and several Gujarat sites, suggesting that rice cultivation expanded during or after the decline phase in tandem with the eastward population movement documented in the settlement pattern data. The appearance of rice in the Gangetic plain during the Late Harappan period has been proposed as a demographic signal of IVC-related population dispersal, with the cultivators carrying rice agriculture from the eastern IVC distribution zone into the Gangetic piedmont zone during the second millennium BCE. Millets — including sorghum, pearl millet, and finger millet — are attested from the late third millennium onwards, reflecting the incorporation of African domesticates that arrived in South Asia via the Arabian Peninsula and the Gulf corridor, a pathway consistent with the IVC's documented maritime connections. The combination of wheat and barley agriculture in the north and west, rice in the east, and millets as a drought-resistant supplement across multiple zones indicates that the IVC subsistence economy was substantially more ecologically diverse than the early emphasis on the Indus floodplain as a wheat-and-barley agricultural system suggested.

Chapter 22

Epigraphy of the Indus Script: Positional Analysis and Sign

Clusters

22.1 Terminal and Initial Sign Classes

Among the most replicable findings of distributional analysis of the Indus corpus is the identification of sign classes defined by their strong positional preferences within inscriptions. This positional structure is one of the corpus's clearest formal regularities and is the primary input to all proposed grammatical interpretations. **Definition EP.1: Terminal and Initial Sign Classes in the Indus Corpus.** Distributional analysis of the Mahadevan Concordance corpus, following Parpola (1994) and computerised re-analyses (Yadav et al. 2010; Wells 2015), identifies two robust positional classes: Terminal signs: A set of approximately 10–15 signs that appear preferentially in the final position of inscriptions, often following what appears to be the main content of the inscription and occurring with a frequency in final position that is 3–8 times their expected frequency un- der a

positional-independence model. In logosyllabic scripts with inflectional morphology, final-position sign concentration is consistent with case endings, nominal markers, or verb in- flections. Under the Dravidian hypothesis, these would correspond to Dravidian case suixes; under a logographic interpretation, they might be determinatives classifying the inscription's content category. Initial signs: A smaller class of approximately 5–8 signs with strong initial-position pref- erences, plausibly corresponding to determinatives, title markers, or object-class indicators in a logosyllabic reading, or to speech particles or honorifics in a phonographic reading. **Finding EP.1: The Positional Structure Is** Robust to Corpus Splitting. The terminal- sign class identified by distributional analysis is reproducible when the corpus is split: signs identified as terminal in the first half of the corpus (sorted by site of origin) maintain their ter- minal preference in the second half, and the identification is consistent across different corpus partitions and different sign-identification conventions (different splitter/lumper choices in the sign inventory). This robustness is not universal across all proposed sign classes — some groupings are artifacts of specific transcription conventions — but the terminal/initial distinc- tion survives methodological variation, giving it stronger epistemic status than sign clusters identified only under specific analytical conditions.

22.2 The Fish Sign Complex: A Detailed Analysis

The fish sign and its compounds constitute the most extensively analysed sub-corpus within the Indus sign inventory, partly because of Parpola's extended analysis of their potential Dravidian readings and partly because the fish is one of the few Indus signs whose pictographic antecedent is relatively uncontroversial. **Case Study EP.1: Fish Sign Compounds and the Rebus** Hypothesis. The basic fish sign is modified in several systematic ways within the Indus corpus: signs are attested with one, two, three, four, and five strokes added at specific locations relative to the fish body. In Par- pola's framework, the basic sign encodes proto-Dravidian *min (fish) via direct pictography; the modified forms encode related words through a combination of rebus and semantic exten- sion: *min also means "star" in some Dravidian languages (a semantic connection between fish and stars attested in Tamil and other Dravidian traditions), and the number strokes on the modified fish signs encode numeral-fish compound readings corresponding to planet names and divine titles in the Dravidian tradition. This extended analysis is internally con- sistent within the Dravidian hypothesis but contains several degrees of freedom: the semantic fish-star connection is not universal across Dravidian languages, the stroke-numeral identifi- cation requires a specific direction (horizontal vs. vertical strokes encoding different values), and the divine-title readings cannot be independently verified without a phonological anchor. Parpola's analysis is therefore best read as a hypothesis generating testable predictions (if the reading is correct, the signs with multiple strokes should appear in contexts where divine or celestial references would be expected), not as a confirmed decipherment.

22.3 Computational Bigram and Trigram Analysis

Proposition EP.1: Bigram Statistics and the Grammar of the Corpus. Bigram analysis — the systematic tabulation of which sign pairs appear together with frequencies above or below chance expectation — produces a directed graph of sign co-occurrence preferences that constitutes the most complete formal characterisation of the Indus corpus's internal structure currently available. This graph has the following properties: (a) it is sparse, meaning that most sign pairs do not co-occur at all and the corpus's structure is captured by a relatively small number of strongly preferred pairings; (b) the high-frequency bigrams form a connected core cluster (a small number of signs that co-occur with each other and with many other signs, consistent with grammatical function words or morphological markers), surrounded by a periphery of signs that appear in fewer bigrams (consistent with content

signs encoding specific referents); (c) the directed bigram structure is consistent with the SOV grammatical typology of Finding 15.1 but does not uniquely confirm it, since several other grammatical typologies produce similar bigram sparsity and connectivity profiles.

Chapter 23

Mohenjo-daro: A City Without a Name

23.1 The Site and Its Archaeology

Mohenjo-daro (literally "mound of the dead" in Sindhi, a post-IVC name applied by local inhabitants of unknown accuracy) is the most extensively excavated IVC urban centre and the site from which the standard image of IVC urban planning derives. Its excavation history, spanning from the 1920s through the 1960s under successive British and Pakistani archaeologists (John Marshall, Ernest Mackay, Ahmad Hassan Dani), has produced the primary dataset for reconstructing IVC urban organisation. **Definition MD.1: Mohenjo-daro's Urban Organisation. Mohenjo-daro covered approximately 250 hectares in its peak Mature Harappan phase, divided into two main sectors: The Citadel** (Upper Town): A raised, purpose-built mound approximately 12 metres above the lower city, with a fired-brick podium supporting a suite of large public buildings in- cluding the Great Bath, a large multi-roomed structure interpreted as a granary or warehouse, an assembly hall, and several smaller structures. The Citadel was enclosed by a substantial fired-brick wall or embankment, possibly for flood protection as much as for defence. The Lower Town: The residential and craft-production area, laid out on a rectilinear grid of major east-west and north-south streets (approximately 9–10 metres wide for the major arteries), with smaller lanes subdividing the blocks. Houses were built of standardised fired brick, typically arranged around internal courtyards, with the street-facing walls often blank (windows and entrances opening onto the internal courtyard), a spatial organisation that prioritises household privacy and is consistent with a climate strategy keeping the interior cool during hot months. **Finding MD.1: The Municipal Sanitation System as an Institutional Indicator. The most** remarkable feature of Mohenjo-daro's built environment from an administrative stand- point is not its scale but its maintenance implications. The covered municipal drain system — brick-lined channels running under the main streets and connected to individual houses via secondary drains with settling chambers — required not only initial construction but pe- riodic cleaning, repair, and expansion as the city developed. Blocked drains, damaged brick linings, and settlement chambers that filled and were dug out are all archaeologically visi- ble in the stratigraphy of the drain system, indicating active maintenance over an extended period. This maintenance regime required: (a) a workforce suiciently organised to clean drains on a regular schedule (the accumulation sequences in settling chambers suggest clean- ing intervals of months to a few years); (b) an authority empowered to mandate household connections to the public system and to enforce maintenance standards; (c) a resource allocation mechanism providing the labour and materials for both routine maintenance and pe- riodic reconstruction. None of these institutional features is visible as an administrative text or a spatial marker of authority (no palace, no identifiable administrative building); they are visible only in the infrastructure they maintained. The drain system is therefore the clearest archaeological evidence that

some form of effective civic authority existed at Mohenjo-daro — authority without a visible institutional home in the archaeological record, and without a readable archive.

23.2 The "Priest-King" and Iconographic Interpretation Problems

Note MD.1: The "Priest-King" and Its Uncertain Reading. The steatite bust excavated from Mohenjo-daro's DK-G area in 1926, depicting a bearded figure with a trefoil-patterned robe and a headband, was rapidly assigned the label "Priest-King" in the early excavation literature and has retained this designation in popular accounts. This label encodes two interpretations: (a) that the figure is a representation of an actual individual, rather than a deity, standardised type, or votive image; (b) that this individual exercised a form of combined religious and political authority of the Mesopotamian priest-king type. Neither interpretation is supported by evidence that would satisfy current standards of archaeological interpretation. The label "Priest-King" is a 1920s scholarly hypothesis that has achieved the status of a common noun through repetition. The figure is unusual — its quality is high, its iconographic elements are distinctive — but its social and political referent is not established by the object itself or by any associated text, since the objects found near it bear undeciphered Indus inscriptions.

23.3 The Destruction Question Revisited

Proposition MD.1: The Late Phase and the Evidence Against Military Destruction. The upper layers of Mohenjo-daro's late Mature and terminal phases were interpreted by early excavators (Wheeler 1947) as displaying evidence of violent destruction, citing the disarticulated skeletal remains found in several street contexts, the apparent sudden end of building activity, and the general state of the upper strata. These observations supported Wheeler's "Aryan invasion" interpretation that dominated mid-20th-century scholarship. Subsequently, the disarticulated skeletal remains have been reanalysed (Kennedy 1984; Jansen 1993) and found to: (a) not constitute a statistically unusual concentration of unburied individuals compared to chronic mortality rates in dense urban populations; (b) lack the trauma signatures (blade injuries, arrow-head wounds) that would distinguish battle victims from individuals who died during an urban decline phase; (c) represent multiple different time periods, not a single catastrophic event. The archaeological evidence at Mohenjo-daro is consistent with prolonged urban decline and gradual abandonment, not with a single military assault.

Chapter 24

Modern South Asian Identity and the IVC: A Political

Sociology of the Debate

24.1 The Stakes of the Question

The IVC's unresolved questions do not merely concern Bronze Age history. They bear directly on contested claims about cultural priority, national identity, and religious legitimacy in a country of 1.4 billion people with a history of intercommunal violence partly organised around claims about whose culture is more authentically "Indian". Understanding the political sociology of the debate is not a distraction from the scholarly analysis; it is a necessary component of understanding why the scholarly analysis has been received as it has. **Definition PS.1: The Two Primary Nationalist Narratives Concerning the IVC** Two politically invested narratives about the IVC compete in contemporary South Asian public discourse, each with a specific institutional home and a specific political valence: The Hindu Nationalist Narrative: Associated with the ideological orbit of the Rashtriya Swayamsevak Sangh (RSS) and its ailiated organisations, this narrative holds that the IVC was the original Vedic civilisation, that its population spoke Sanskrit or a Sanskrit antecedent, that the Aryan invasion model was a British colonial fabrication de- signed to delegitimise India's cultural achievements, and that modern Hindus are the unbroken cultural continuation of the IVC tradition. This narrative requires the OOI lin- guistic hypothesis (Chapter 7) and a specific reading of the genomic evidence (Steppe

ancestry as either absent from South Asia entirely or as having originated in South Asia) that is inconsistent with the current specialist consensus. The Dravidian Identity Narrative: Associated primarily with Tamil political move- ments, this narrative holds that the IVC was a Dravidian civilisation and that the Aryan migration (accepted as real under this narrative) displaced or marginalised an older Dra- vidian cultural tradition that survives in South India. This narrative supports the Dravid- ian linguistic hypothesis and accepts the IAM model's genomic component while draw- ing different political conclusions from it — emphasising the prior existence of a distinct Dravidian civilisation rather than a unified "Indian" civilisation. **Finding PS.1: The Asymmetric Political Stakes and Their Scholarly Effects. The two narratives have** asymmetric stakes and asymmetric effects on the scholarly literature. The Hindu nationalist narrative operates at the level of national identity and cultural priority for the world's most populous Hindu-majority nation, with institutional support from government funding agencies and political access that the Dravidian narrative does not match at the national level. The result is a documented pattern (see Proposition 3.1's reference to Hakenbeck 2019 and the wider literature on nationalism and ancient DNA) of: (a) selective

citation of IVC scholarship in public discourse, with findings consistent with the preferred narrative amplified and contradictory findings minimised or attributed to foreign bias; (b) institutional pressure on Indian archaeologists and genomicists that has been documented in whistleblower accounts and journalistic investigations; (c) a segment of the Indian academic publishing space in which peer review standards for IVC claims are applied asymmetrically, with OOI-consistent papers receiving less rigorous methodological scrutiny than IAM-consistent papers in the same venues. These patterns do not validate any particular substantive position in the IVC debate; they explain a feature of the reception literature that would otherwise be puzzling to a reader approaching the field solely through internationally peer-reviewed journals.

24.2 The Archaeological Survey of India and Its Institutional Position

Note PS.1: The Archaeological Survey of India Under Political Pressure. The Archaeological Survey of India (ASI), the government body responsible for excavation permits and heritage site management in India, operates under the jurisdiction of the Ministry of Culture and is therefore subject to political influence in its research priorities. Several journalists and archaeologists have documented shifts in ASI research emphases and public communications consistent with the political preferences of successive governments, including an increased institutional emphasis on the Saraswati river identification and Vedic cultural continuity claims that post-date changes in national government. This institutional pressure does not determine the published findings of individual researchers within the ASI system, many of whom have maintained international peer-review standards; it does influence which projects receive funding and institutional support, and it shapes the institutional communication of archaeological findings to the public. A reader evaluating ASI-issued press statements about IVC findings should apply an additional layer of critical scrutiny regarding the distinction between published peer-reviewed findings and institutional communications, which may reflect political messaging as well as scientific content.

24.3 The International Scholarly Community's Response

Proposition PS.1: International Scholarship as a Partial Check on Politicised Reception. The primary check on politically motivated distortion of IVC scholarship is the international peer-review community, which lacks the specific political investments of South Asian national identity debates and can evaluate IVC claims against a comparative Bronze Age record and methodological standards

developed in other geographical contexts. The international literature on South Asian archaeogenomics (Reich, Patterson, Narasimhan, Metspalu and colleagues, working from institutions in Europe, the United States, and Estonia) has been no- tably more resistant to the political pressure documented in Note PS.1 than segments of the Indian national academic literature, partly because the genomic methods are mathematically explicit and the results are independently replicable from the raw data, which is deposited in public repositories (the European Nucleotide Archive, the NCBI Sequence Read Archive). This does not make the international literature immune to all bias, but it provides a mecha- nism for independent verification that institutional political pressure cannot easily neutralise, and it is the reason that the genomic findings reviewed in Part I are treated in this volume as a more reliable source of Tier 1 evidence than institutional communications from politically invested sources.

Chapter 25

Seals, Sealings, and the Administrative Function of the Indus

Script

25.1 The Seal Technology

The stamp seal — a carved stone object bearing an inscription and typically an animal motif, used to impress a mark in wet clay — is the primary medium of the Indus script and the defining artefact type of the Mature Harappan period. Understanding its technical and functional properties is prerequisite to evaluating both its administrative role and the decipherment constraints of

Chapter 26

Definition SEAL.1: The Indus Stamp Seal — Technical Specifications. Mature Harap- pan stamp seals

are characterised by a consistent set of technical features across sites sepa- rated by hundreds of kilometres: Material: The great majority are carved from steatite (soapstone), a soft material easily worked with copper tools that hardens when fired. A minority are made from faience (glazed ceramic), shell, or terracotta. The steatite was apparently fired after carving, as evidenced by the characteristic white surface oxidation visible on most excavated examples. Dimensions: The standard "square seal" measures approximately 2.5 × 2.5 cm, with a thickness of approximately 0.7–1.0 cm; the reverse bears a perforated boss for handling. This consistent standardisation implies a convention suiciently stable to constitute a de facto stan- dard, and is consistent with the weight standardisation of Definition T.1 as evidence of IVC- wide conventional norms. Inscription placement: Inscriptions are placed above the animal motif on the seal face, reading right-to-left in the mirror-image orientation required for impressed clay to read left- to-right (or, from the perspective of the seal's user, right-to-left as in Definition 5.1). The in- scription typically runs to 3–8 sign-tokens, consistent with a short identifying label (a proper name, a title, a trading category, or some combination). The unicorn motif: By far the most common motif in the seal corpus (approximately 60bovine or equine animal shown in profile with a single horn, facing an incense burner-like object — is one of the IVC's great unresolved iconographic puzzles. It appears to be a real animal type within the IVC's symbolic system (it is too consis- tently depicted to be a perspective rendering of a two-horned animal), but it has no obvious naturalistic referent. Whether it is a mythological creature, a composite animal combining features of known species, or an abstract heraldic emblem, its function in the seal system — most likely marking a specific social group, trading category, or institutional ailiation — cannot be determined without a readable inscription context. **Finding SEAL.1: Sealings and the** Evidence for Administrative Use. Alongside seals, numerous sealings — lumps of clay bearing seal impressions — have been excavated from IVC

sites, particularly from Mohenjo-daro and Harappa. Several sealings show both a seal impres- sion on the front and rope or matting impressions on the back, consistent with their having been used to seal packages, bales, or containers for transit, with the clay sealing pressed over a knot or tie and then impressed with the seal to certify the package's integrity. The sealing context is the clearest archaeological evidence that the Indus script served, among other functions, a commercial or administrative one: the label on a sealed package presumably identified the package's origin, owner, contents, or destination (or some combination). This functional parallel to known administrative uses of seals in Mesopotamia is the primary ba-

sis for the assumption that Indus inscriptions encode linguistically meaningful administrative content rather than purely ritual or decorative marks — an assumption that is supported, but not proven, by the Rao et al. conditional entropy analysis of Chapter 13.

26.1 The Copper Tablet Corpus

A subset of the Indus inscribed corpus consists of copper tablets, typically smaller than stamp seals and often bearing text on both sides. These are functionally distinct from the clay seal- ings and appear to have been produced as durable objects rather than for one-time adminis- trative use. **Case Study SEAL.1: The Mohenjo-daro Copper Tablets and Long Inscriptions. Among the longest Indus** inscriptions are those on a group of copper tablets from Mohenjo-daro, in- cluding the previously mentioned 26-sign example. Copper tablets are rare in the corpus but disproportionately important for distributional analysis because their greater length provides more bigram and trigram instances per object, allowing higher-resolution statistical charac- terisation of sign co-occurrence patterns. The longest inscriptions also provide the best data for identifying long-range dependencies in the sign sequence — the kind of structural infor- mation that transformer-based models with extended context windows are best equipped to extract. However, the copper tablet inscriptions do not obviously differ in structural type from the stamp seal inscriptions, suggesting that the length difference reflects content quan- tity rather than a different functional genre: a longer version of the same kind of label or administrative text, rather than a qualitatively different document type.

26.2 Inscribed Objects Beyond Seals

Proposition SEAL.1: The Heterogeneity of the Inscription Corpus. The Indus script appears on a broader range of object types than the seal/sealing pair alone, and this heterogeneity has implications for hypotheses about the script's function. Inscribed objects include: (a) pottery, with inscriptions incised before firing (pre-firing graiti) and after firing (post-firing graiti); (b) terracotta tablets, some with seal-like iconography and some without; (c) metal tools and implements; (d) the ivory rod from Mohenjo-daro bearing an inscription; (e) stone objects including weights. The presence of inscriptions on fired pottery (which was widely distributed across sites and across social contexts, unlike the seals which may have been restricted to commercial elites) is among the evidence suggesting that literacy, or at least familiarity with the script, extended beyond a narrow administrative class. However, the pottery inscriptions are typically shorter than seal inscriptions (often single signs), reducing their informative value for distributional analysis.

Chapter 27

The Indus Script and the Question of Literacy

27.1 What Literacy Claims Require

The question of how widely the Indus script was understood by the IVC's population is not a merely academic question. It bears on the likely administrative structure of the civilisation (a narrow scribal

class versus a broader literate population), on the likely size and diversity of the original text corpus (of which the surviving seals are a preservational residue), and on what kind of institution the script served. **Definition LIT.1: Operational and Receptive Literacy. Following the distinction conven- tional** in studies of ancient literacy: Operational literacy: the ability to produce (inscribe, write) new text. In Bronze Age administrative contexts, operational literacy was typically restricted to trained scribes within an institutional framework (temple, palace, trading house) and was rarely widespread across the general population. Receptive literacy: the ability to read (recognise and understand) existing inscriptions. Receptive literacy can be significantly broader than operational literacy in a system where text is encountered mainly in standardised forms (labels, marks, seal impressions); a mer- chant who cannot produce an inscription may be able to recognise and interpret the specific inscription categories relevant to their trade without having the operational skill of inscription production. The distinction matters for the IVC because the archaeological evidence (pottery graiti widely distributed across social contexts) might indicate widespread receptive literacy while remaining consistent with more restricted operational literacy, a pattern documented in other Bronze Age administrative systems. **Finding LIT.1: No Evidence for Scribal Schools or Dedicated Writing Materials. In Mesopotamia and** Egypt, scribal literacy was maintained by formal schools (edubba in Sume- rian, House of Life in Egyptian), the archaeological evidence for which includes large quanti- ties of student exercise tablets bearing repeated sign-lists, practice texts, and correction marks. No comparable evidence for formal scribal training has been identified in the IVC archaeo- logical record: no large deposit of practice inscriptions, no sign-list exercise objects (the kind of systematic enumeration of signs that appears in both early Sumerian and Egyptian edu- cational contexts), and no architectural context plausibly identified as a scribal school. This absence is consistent with a more informal transmission of literacy — perhaps within craft or commercial families rather than through institutional education — but it cannot be taken as definitive evidence that no such institutions existed, given the IVC's general archival silence and the possibility that educational materials were produced on perishable media (wood, palm leaf) that have not survived.

27.2 The Graiti Record

Case Study LIT.1: Pre-Firing Pottery Inscriptions and Craft-Level Literacy. Pre-firing inscriptions on pottery — marks incised into the clay before the vessel was fired, so that they are permanent and were clearly intended from the object's production stage — are found at both urban sites and smaller settlements, at a frequency consistent with routine mark-making by potters rather than exceptional administrative labelling. The marks are often single signs, sometimes the same sign repeated across multiple vessels from the same site, suggesting that a single sign functioned as a potter's mark (a craft identity label) rather than as a complex linguistic message. This pattern is consistent with what has been called "restricted literacy" in Bronze Age craft contexts: a narrow set of signs familiar to practitioners of specific crafts, used for craft identity and administrative tracking without implying full operational literacy in the complete sign inventory. The pre-firing pottery marks are therefore ambiguous evidence for the nature of Indus literacy: they show that the script's signs (or a subset of them) were used by craft producers, not only by an administrative elite, but they do not resolve whether craft producers could produce or read more complex multi-sign inscriptions.

Chapter 28

Genetics, Language, and Continuity: The Modern South Asian

Population

28.1 ANI and ASI in the Modern Genome

The genetic structure of modern South Asian populations has been characterised in detail since Reich et al. (2009, Nature) proposed the two-component model of Ancestral North In- dian (ANI) and Ancestral South Indian (ASI) ancestry. Understanding this structure is nec- essary for evaluating claims about IVC population continuity with the present. **Definition MG.1: ANI and ASI — Revised Definitions Post-Narasimhan et al.** Reich et al.'s (2009) original ANI/ASI model has been substantially revised by Narasimhan et al.'s (2019) ancient-DNA data. In the revised framework: ANI (Ancestral North Indian): Not a single ancestral population but a composite formed by admixture between Indus Periphery Cline de- scendants (Part I) and Steppe- related populations entering South Asia from approximately 2000 BCE. ANI is therefore not a direct descendant of the IVC population but an admixed derivative of it. ASI (Ancestral South Indian): Formed primarily from the mixing of Indus Periphery Cline descendants (again) with AASI-related populations in southern and eastern South Asia, without the significant Steppe admixture component that characterises ANI. ASI ancestry is highest in tribal and lower-caste populations in peninsular India. Both ANI and ASI, in this revised framework, share an Indus Periphery Cline component as a significant an- cestral element, meaning that the IVC's population genetics are genuinely ancestral to essen- tially all modern South Asians — both the northern, Steppe- admixed populations (through their ANI component) and the southern, AASI-admixed populations (through their ASI com- ponent). **Finding MG.1: The IVC as a Common Ancestor — A Genuine Finding With Con- strained** Implications. The finding that virtually all modern South Asians, across caste, lin- guistic, and geographic divisions, share a substantial component of Indus Periphery Cline an- cestry is a genuine and non-trivial genomic finding. It establishes a degree of biological conti- nuity between the IVC's population and the contemporary South Asian population that is not metaphorical or cultural but is reflected in actual allele frequencies at hundreds of thousands of genomic loci. This finding has been accurately cited in contexts emphasising the IVC's re- lationship to contemporary South Asian populations. Its implication is carefully bounded, however, by the tier-distinction framework of **Definition 0.1: the shared ancestry does not determine which contemporary population's linguistic or** cultural tradition was most closely connected to the IVC, since the admixture processes that formed ANI and ASI mixed Indus Periphery ancestry with both Steppe and AASI components in different pro- portions across different population groups, producing a pattern in which no single modern

population is simply the direct continuation of the IVC in the sense of having remained genetically unmixed with post-IVC arrivals.

28.2 Caste Structure and Genomic Endogamy

Proposition MG.1: Endogamy and the Preservation of Ancestry Structure. A distinctive feature of South Asian population genetics, relative to most other world regions, is the exceptional degree to which caste-associated endogamy has preserved ancestry differentiation over timescales of 2,000–3,000 years. Moorjani et al. (2013, American Journal of Human Genetics) estimated admixture dates for numerous Indian caste groups and found that most endoga- mous caste communities have maintained their specific ANI/ASI proportions with minimal further admixture for 60–100 generations — approximately 1,500–3,000 years. This endogamy effect means that the Indian caste system's

ancestry structure is, to an unusual degree, a pre- served record of which populations mixed with which at the point of the IVC's decline and the Steppe migration's penetration into South Asia. Reading that record requires the sophisti- cated statistical genomics reviewed in the present account's appendices; it does not, however, translate directly into claims about cultural or linguistic continuity, since language and cul- tural practice can and do change within endogamous populations without genetic change.

28.3 The Genetic Distance Between IVC and Modern Populations

Case Study MG.1: and the IVC's Position in South Asian Genetic Space. Wright's fixation index , a standard measure of genetic differentiation between populations, can be used to place the IVC's Indus Periphery Cline individuals in the genetic space of modern South Asians. The analysis in Narasimhan et al. (2019) shows that Indus Periphery individ- uals are closest to modern Iranian and South Asian populations that have low Steppe ances- try and moderate AASI ancestry — populations concentrated in parts of Iran, Pakistan, and southern India. They are not closest to the high-Steppe-ancestry populations of northwestern India and Pakistan who speak Indo-Aryan languages, nor closest to the high-AASI popula- tions of Andaman and other tribal groups. This positioning is consistent with the IVC's role as a mixing population intermediate between the AASI and Iranian farmer sources, ances- tral to both ANI and ASI through different subsequent admixture paths, and not uniquely ancestral to any single modern linguistic or caste group.

Chapter 29

Urban Planning and Civic Infrastructure

The IVC's urban centres exhibit a degree of physical standardisation that has no close parallel among contemporary Bronze Age civilisations, and that standardisation is itself a form of evidence requiring interpretation independent of, but consistent with, the genomic and chronological findings of Parts I and III.

29.1 The Citadel-and-Lower-Town Layout

Definition MC.1: The Bipartite Urban Plan. The majority of large Mature Harappan settlements — Mohenjo-daro, Harappa, Kalibangan, Dholavira, and Surkotada among them — share a recurring spatial organisation consisting of a raised, walled citadel mound (typically to the west) containing public or administrative structures, and a larger, lower-lying residential mound containing the bulk of domestic architecture, craft workshops, and street grids. The citadel's elevation was achieved by constructing platforms of mud brick and rubble fill, in some cases ten metres or more above the surrounding plain, a labour investment that implies coordinated planning and a workforce mobilisable for purposes other than immediate subsistence. Whether the citadel-lower town division reflects a functional separation (administrative versus residential), a status separation (elite versus non-elite), or primarily a flood-management strategy (the citadel as refuge above seasonal inundation) remains debated, and the evidence does not cleanly discriminate between these explanations, which are in any case not mutually exclusive. **Finding MC.1: Grid Orientation as Evidence of Planning** Intent. The street grids of Mohenjo-daro and Harappa are oriented close to the cardinal directions, with main thorough- fares running north-south and secondary lanes running east-west at roughly perpendicular angles, a pattern documented across multiple excavated sectors and not confined to a

sin- gle building phase. This orientation consistency across centuries of rebuilding — structures were demolished and rebuilt on the same alignment repeatedly, as stratigraphic sequences at Mohenjo-daro show — indicates that the grid was not an incidental by-product of organic growth but an enforced planning convention, maintained by some mechanism of social or administrative coordination whose institutional form is not recoverable from the architec- ture alone. This is consistent with, but does not by itself establish, the existence of centralised urban authority; the conformity could equally be explained by a strong shared building con- vention enforced through community consensus rather than top-down administrative fiat, a distinction the archaeological record cannot resolve.

29.2 The Drainage System

Case Study MC.1: Mohenjo-daro's Sewerage Network. Mohenjo-daro's drainage infrastructure is the most extensively documented in the Bronze Age archaeological record. Individual houses were equipped with bathing platforms and, in many cases, latrines connected by brick-lined chutes to channels running beneath the streets; these street-level drains, covered with removable brick or stone slabs to permit periodic cleaning, fed into larger collector drains that in turn discharged outside the settlement boundary. Soak pits and sediment traps were incorporated at intervals to capture solid waste before it entered the main channels, reducing blockage. No contemporary Mesopotamian or Egyptian urban centre exhibits drainage provision at this density or this degree of standardisation across residential structures of varying size and apparent wealth, which Jansen (1989) and subsequent reassessments have read as evidence that sanitary infrastructure was treated as a civic good extended broadly across the urban population rather than reserved for elite quarters — though the absence of comparably excavated residential sectors at other Bronze Age cities makes this a claim about relative documentation as much as a claim about relative provision.

29.3 Brick Standardisation

Proposition MC.1: The 4:2:1 Brick Ratio as Evidence of a Shared Metrological Standard. Fired and sun-dried bricks recovered from IVC sites separated by more than 1,500 kilometres — from Shortughaï in northern Afghanistan to sites in Gujarat — conform overwhelmingly to a length:width:height ratio of approximately 4:2:1, a proportion that is mechanically eicient for bonded brick construction (it permits headers and stretchers to interlock without cutting) but is not the only mechanically eicient ratio available, and its near-universal adoption across the IVC's geographic range is therefore better explained as a transmitted convention than as an independent local optimisation repeated by chance at every site. This standardisation, combined with the weight-system standardisation discussed in Chapter 30, constitutes one of the strongest archaeological arguments for some form of inter-regional coordination or shared technical training across the IVC's full territorial extent, independent of whatever administrative or political structure underwrote that coordination.

29.4 The Great Bath and the Problem of Public Architecture

Note MC.1: A Civilisation Largely Without Identifiable Temples or Palaces. The most frequently noted negative finding in IVC urban archaeology is the absence, at any excavated site, of a structure that can be confidently identified as a royal palace, a monumental temple, or a royal tomb of the kind that dominates the archaeological signature of contemporary Mesopotamia and Egypt. The one structure widely interpreted as having a non-domestic, plausibly ceremonial function is Mohenjo-daro's Great Bath: a watertight brick-built tank (ap- proximately 12 by 7 metres, 2.4 metres deep) set within a colonnaded courtyard on the citadel mound, with a sophisticated bitumen-sealed floor and a drainage outlet large enough to sug- gest deliberate, controlled emptying rather than

accidental leakage. Its function — ritual ablution, a form of public bathing analogous to later South Asian tank-temple traditions, or something else entirely — cannot be established from architecture and material remains alone in the absence of the textual sources that illuminate comparable structures in Mesopotamia and Egypt. This absence of monumental religious or dynastic architecture is taken up as a comparative datum in

Chapter 30

Craft Production and Specialisation

30.1 Bead Manufacture and the Long-Distance Carnelian Industry

Definition MC.2: The Etched Carnelian Bead Industry. Carnelian bead production, documented in greatest detail at Chanhu-daro, Dholavira, and the workshop quarters of Khambhat (Gujarat, a bead-working tradition that continues into the present), involved a multi-stage chaîne opératoire: nodule selection, heat treatment to improve the stone's colour and flaking properties, percussion and pressure flaking to rough out the bead blank, drilling with specialised hardened drill bits (the so-called Ernestite and, later, a tapered drill technology unique to South Asia), and, in a distinctive Harappan innovation, surface etching with an alkaline paste (probably a sodium carbonate solution applied with a reed pen) that produces permanent white linear and circular designs upon firing. Etched carnelian beads of recognisably Harappan style have been recovered from Mesopotamian contexts, including the Royal Cemetery of Ur, providing direct material evidence of the long-distance exchange network discussed in

Chapter 31

Finding MC.2: Drilling Technology as a Diagnostic Craft Signature.

Kenoyer's experi- mental archaeology and use-wear analysis of Harappan drill bits has established that the long, narrow, near-perfectly cylindrical perforations characteristic of Harappan carnelian beads required a specialised drill technology — a hard stone or, later, a synthetic material identified as a heat-treated chert ("Ernestite") bit mounted on a bow- or pump-drill apparatus — ca- pable of sustained high-speed rotation without fracturing. The technical sophistication of this drilling technology, reproducible only with diiculty by modern experimental archaeol- ogists working with replica tools, is offered as evidence that craft specialisation in the IVC had reached a level of technical refinement requiring dedicated training and probably hered- itary or guild-like transmission, a form of economic organisation that does not require, but is compatible with, centralised administrative oversight.

31.1 Shell Working and Faience

Case Study MC.2: Chank Shell Bangles and Coastal-Inland Exchange. The chank shell (**Turbinella** pyrum), harvested from the coastal waters of Gujarat and the Makran, was worked into bangles, ladles, and inlay pieces at specialised workshop sites including Nageshwar and Bagasra on the Gujarat coast; the finished or semi-finished products were then distributed inland to consumption sites across the IVC's territory, a pattern documented through shell-species sourcing studies that match the raw material to its specific coastal collection zone. This shell-working industry, alongside the steatite seal-carving industry and the faience bead and bangle industry (faience being a glazed, quartz-paste ceramic requiring controlled-atmosphere kiln firing), illustrates a broader pattern of regionally specialised craft production integrated through an exchange network spanning the IVC's full geographic extent — a pattern of economic integration for which no comparably detailed administrative textual record survives, in contrast to the cuneiform archives that document craft specialisation in contemporary Mesopotamia.

31.2 Copper-Bronze Metallurgy

Proposition MC.2: A Tin-Poor Bronze Tradition. Harappan metallurgy worked primarily in unalloyed copper and in copper alloyed with arsenic or, more rarely, with tin, but true tin-bronze is markedly less common in IVC metal assemblages than in contemporary Mesopotamian or Anatolian contexts, a pattern consistent with the IVC's distance from the major tin sources of Central Asia (the Zeravshan valley deposits) and the Gulf trade routes

that supplied Mesopotamia. Copper itself was sourced primarily from the Aravalli range (Khetri zone, Rajasthan) and from Oman (Magan, in the cuneiform sources discussed in Chapter 31), with lead-isotope sourcing studies of IVC copper artefacts showing a mixed signature consistent with both sources contributing to the metal supply at different sites and periods. The comparative scarcity of bronze relative to Mesopotamia is not evidence of technological backwardness — Harappan smiths produced sophisticated lost-wax cast bronze figurines, including the well-known "Dancing Girl" of Mohenjo-daro — but rather reflects the IVC's specific position in the Bronze Age tin-supply network, a structural rather than a cognitive constraint.

Chapter 32

The Indus Weight and Measurement System

32.1 The Binary-Decimal Weight Series

Definition MC.3: The Harappan Weight Standard Cubical and near-cubical weights of polished chert, recovered in the thousands from IVC sites across the civilisation's full territorial range, conform to a standardised series in which the small weights follow a binary progression (1, 2, 4, 8, 16, 32, 64 units) be- fore transitioning, at the higher end of the series, to a decimal progression (160, 320, 640, 1,600, 3,200, 6,400, 12,800 units), with the base unit corresponding to approximately 0.86 grams in the reconstruction of Mackay (1938) and Hemmy (1931), refined by subsequent metrological studies. The consistency of this weight standard — measured by the statisti- cal clustering of recovered weight masses around the predicted series values, rather than a smooth or random distribution — across sites separated by more than a thousand kilometres and, on the chronological evidence reviewed in Chapter 9, several centuries, is among the most quantitatively rigorous pieces of evidence for IVC-wide economic stan- dardisation available to archaeology. **Finding MC.3: Statistical Confirmation of the Weight Series. Quantitative reanalysis of large weight** assemblages (notably the statistical study of Mohenjo-daro and Harappa weights by Miller (2013) building on the original metrological work of Hemmy) confirms that the masses of recovered weights cluster in statistically distinct modes corresponding to the predicted binary-decimal series rather than approximating a continuous distribution, and that the modal spacing is consistent across the assemblages examined from geographically separated sites. This statistical regularity is diicult to explain except as the product of a shared, transmitted, and enforced measurement standard — whether enforced through for- mal administrative mechanisms (state-issued reference weights, as in contemporary Mesopotamia) or through a less formal but equally effective convention maintained by merchant practice and cross-checking cannot be determined from the weights alone, and the distinction matters for the heterarchy-versus-hierarchy debate taken up in

The internal logic of the weight system reflects a sophisticated administrative consciousness. The binary series accommodates rapid halving and doubling — operations particularly useful in trade contexts where quantities needed to be divided among parties or scaled across different transaction sizes. The decimal extension into higher values (160, 200, 320, 640 units) suggests a practical hybridisation: binary arithmetic for small-scale precision, decimal scaling for large consignments. This dual structure has no precise parallel in contemporary Mesopotamian metrology, which employed sexagesimal principles throughout, suggesting the IVC system emerged from an independent metrological tradition. The degree of standardisation across sites separated by hundreds of kilometres implies either a centralised

production mechanism for weights, or a remarkably effective dissemination of metrological norms through commercial networks. Kenoyer (1997) has proposed that the standardisation of weights was a key instrument of administrative integration across the dispersed IVC urban system, functioning as a substitute for any centralised political authority. The absence of royal or state iconography on the weights makes the mechanism of enforcement unclear: standardisation may have been maintained through guild structures, merchant associations, or reputational sanctions operating through long-distance exchange relationships rather than through coercive state power.

Chapter 33

30.2 Linear Measurement

Case Study MC.3: The Lothal and Mohenjo-daro Scale Fragments. A fragmentary ivory scale recovered from Lothal, with graduated divisions of approximately 1.7 millimetres, and a fragmentary shell scale from Mohenjo-daro with comparable graduations, have been used to reconstruct a Harappan linear unit (variously estimated at approximately 33.5 centimetres,

sometimes termed the "Indus foot" or "Indus cubit" depending on the proposed derivation) whose proposed correspondence to recurring dimensions in Harappan brick architecture (the brick module discussed in Chapter 28) has been argued, though not universally accepted, to indicate a single integrated system of length and weight standardisation governing both con- struction and exchange. The small number of surviving scale fragments (fewer than half a dozen securely identified examples across the entire excavated corpus) means that this recon- struction, while internally consistent, rests on a narrower evidentiary base than the weight- series reconstruction of Definition MC.3, and should be treated with correspondingly greater caution.

The absence of palatial architecture, royal tombs, and centralised storage facilities of Mesopotamian scale has led many scholars to conclude that the IVC lacked a state in the conventional sense. Possehl (2002) proposed the concept of a Faceless Indus State, emphasising the paradox of evident large-scale coordination without identifiable coordinators. An alternative framework draws on the heterarchy concept: power distributed across multiple, non-ranked institutions rather than concentrated in a single apex. Craft guilds, merchant associations, priestly bodies, and neighbourhood councils may each have exercised domain-specific authority without any single institution subordinating the others. Kenoyer (1997) argued that control over the standardised weight system, the seal production network, and access to prestige raw materials constituted a dispersed form of economic governance that did not require concentrated coercive power. The uniformity of brick ratios, street orientations, and drainage systems across hundreds of kilometres is consistent with shared institutional norms rather than top-down imposition, though distinguishing between these mechanisms archaeologically is difficult. The heterarchy model remains heuristically productive precisely because it refuses to project familiar state structures onto evidence that does not require them, though it faces the challenge of specifying the actual mechanisms by which heterarchical coordination was achieved and maintained across the scale and geographic extent of the IVC system, which substantially exceeds that of most historically documented heterarchies.

Chapter 34

Trade Networks: Mesopotamia, the Gulf, and Meluhha

34.1 The Cuneiform Evidence for Meluhha

Definition MC.4: Meluhha in the Mesopotamian Textual Record. Sumerian and Akkadian cuneiform texts from the late third millennium BCE refer repeatedly to a distant land called Meluhha, alongside the closer trading partners Dilmun (identified with Bahrain and the adjacent Gulf coast) and Magan (identified with Oman and the southeastern Arabian peninsula), as a source of specific commodities — carnelian, lapis lazuli (via re-export, since the primary lapis source lay in Badakhshan, well beyond Meluhha), exotic woods, ivory, and, in several texts, a type of dog or bird unfamiliar to Mesopotamian readers. An inscription of Sargon of Akkad (circa 2334–2279 BCE) boasts that ships from Meluhha, Magan, and Dilmun docked at the quay of Akkad, and a later inscription of the ruler Gudea of Lagash (circa 2100 BCE) records the importation of Meluhhan wood and stone for temple construction. The identification of Meluhha with the Indus Valley Civilisation, first proposed on toponymic and commodity grounds and subsequently strengthened by the archaeological recovery of Harappan-style material culture (etched carnelian beads, a Harappan-script seal) in Mesopotamian contexts, is now the consensus position among Assyriologists and Indus archaeologists alike, though the textual record offers no information about Meluhha's internal political organisation, since Mesopotamian scribes had no occasion to record what they did not directly observe or did not consider relevant to their own administrative purposes.

34.2 The Persian Gulf Intermediary Stations

Finding MC.4: Round Seals as a Diagnostic of Gulf-Mediated Exchange. A distinctive class of circular (as opposed to the standard Harappan square) steatite seals, bearing a reduced and partially modified version of Harappan iconography and occasionally combining Indus script signs with motifs absent from the mainland Harappan corpus, has been recovered in quantity from Bahrain (ancient Dilmun) and from Failaka island (Kuwait), and in smaller numbers from sites in eastern Arabia and southern Mesopotamia. The concentration and stylistic in- termediacy of these "Persian Gulf" or "Dilmun-type" seals is read by Gulf archaeologists (During Caspers, Potts, and others) as evidence that Dilmun functioned as an entrepôt — a redistribution point where Harappan goods were trans-shipped, and where local seal-carvers produced a hybrid iconographic style for a Gulf merchant class operating between the Harap- pan and Mesopotamian commercial spheres — rather than as a passive waystation through which Harappan goods moved unchanged. This three-tier structure (Harappan core, Gulf intermediary, Mesopotamian consumer) is consistent with the absence, noted

in Definition MC.4, of any unambiguous Harappan colonial settlement within Mesopotamia proper, sug- gesting that exchange was conducted through intermediary merchant communities rather than through direct

Harappan colonisation of the Mesopotamian coast.

34.3 What the Trade Evidence Does and Does Not Establish

Proposition MC.3: Economic Integration Without Political Unification. The convergent evidence of Mesopotamian textual references, Gulf intermediary seals, and the find-spots of Harappan craft products (etched carnelian, the Ur seal) establishes that the IVC participated in a long-distance maritime and overland exchange network extending from Central Asia (the Shortughaï outpost of Proposition GEO.1) to Mesopotamia, a network of a geographic scale matched among contemporary Bronze Age societies only by the overlapping Egyptian, Levantine, and Mesopotamian trade circuits. This economic integration is sometimes invoked, loosely, as evidence for the IVC's political sophistication or state-level organisation; the inference does not follow without an additional argument, since long-distance exchange networks of comparable geographic scale are documented among societies lacking centralised state apparatus (for instance, several Pacific exchange systems and parts of the pre-state Eurasian steppe network), and the trade evidence alone, independent of the urban-infrastructure evidence of Chapter 28, would not by itself settle the heterarchy-versus-hierarchy question addressed in

Chapter 35

Animal Husbandry and Faunal Evidence

35.1 The Domesticated Animal Economy

Definition MC.5: The Harappan Faunal Assemblage. Zooarchaeological analysis of bone assemblages from excavated IVC sites documents an economy dominated by humped cattle (Bos indicus, the zebu), water buffalo, sheep, and goat, with pig present but proportionally mi- nor at most sites, and with a small but consistent presence of wild fauna (deer, antelope, wild boar, and riverine and marine fish and shellfish at appropriately located sites) indicating that hunting and fishing supplemented, rather than were replaced by, the domesticated-animal economy. The zebu in particular occupies a disproportionate place in the iconographic record relative to its dietary contribution: the humped bull is among the most frequently depicted animals on Harappan seals, a discrepancy between economic and symbolic prominence that recurs in many agrarian societies and is addressed further in

The management of large domesticated animals in an urban context raises questions about spatial organisation and the relationship between urban and rural components of the IVC settlement system. The presence of cattle dung and fodder remains in urban deposits suggests that animals were kept within or adjacent to the urban perimeter, while the scale of the pastoral economy implied by the faunal assemblages suggests that substantial herds were maintained in the hinterland around major urban centres. The articulation between urban-based craft and administrative functions and a rural pastoral and agricultural hinterland that supplied both food and raw materials is a structural feature of Bronze Age urbanism generally, but the mechanisms of this articulation in the IVC — whether through market exchange, tribute, kin-based obligation, or other forms of redistribution — are not documented in the archaeological record with the clarity that cuneiform texts provide for Mesopotamian equivalents.

Chapter 36

32.2 The Absence of the Horse

Note MC.2: Horse Remains in IVC Contexts — A Contested and Consequential Negative. **Claimed** horse (Equus caballus) remains from IVC sites, most prominently from Surkotada, have been the subject of sustained methodological dispute since their initial identification by Sharma (1974); subsequent reanalysis by equid specialists (Meadow and Patel, among others) has argued that the Surkotada material is more consistent with the wild ass (Equus hemionus, the onager or khur) or with domestic ass, both of which were present in the region, than with true domestic horse, on the grounds of tooth morphology and limb-bone proportions that the original identification did not adequately exclude. This dispute matters disproportionately because of its entanglement with the Indo-Aryan migration debate discussed in Chapter 7: the PIE vocabulary for the horse is securely reconstructed (Chapter 7), and the horse's archaeologically attested functional domestication in South Asia dates to the post-Harappan period associated with Steppe-derived ancestry, making the question of whether any horse remains exist in secure Mature Harappan contexts a genuinely consequential empirical question rather than a peripheral taxonomic dispute — and one on which the methodologically more rigorous zooarchaeological literature leans toward a negative answer for the Mature Harappan phase proper.

The Pashupati seal's ambiguous evidence for proto-Shaiva religion illustrates a more general problem in the interpretation of IVC iconography: the difficulty of distinguishing deliberate symbolic communication from the projection of meaning by interpreters trained in later South Asian religious traditions. The seal's central figure has been read as a prototype of Shiva by generations of scholars, but the reading depends on selecting a subset of the seal's iconographic elements — the seated posture, the horned headdress, the animal companions — and assimilating them to a later iconographic scheme while ignoring elements that do not fit, such as the specific combination of animals depicted and the object before which the figure sits. A more cautious reading acknowledges the seal's extraordinary richness without committing to a specific identification and uses it as evidence for the existence of complex ritual or narrative scenes in IVC visual culture rather than as a window onto IVC theology.

Chapter 37

Transport and Exchange Infrastructure

37.1 Riverine and Overland Transport

Case Study MC.4: The Terracotta Cart Figurines as Evidence of Wheeled Transport Terracotta models of bullock-drawn carts, recovered in substantial numbers from Harappan domestic contexts, depict a vehicle with a flat platform body, solid or cross-bar wheels, and a yoke pole for paired draught animals — a design that, on the comparative evidence assembled in the companion Ruota volume, places the Harappan cart within the broader Eurasian Bronze Age tradition of ox-drawn transport rather than representing an independent local invention, consistent with the wheel's attested arrival in South Asia by approximately 2500 BCE noted in

The question of who controlled and coordinated the IVC's exchange infrastructure bears directly on the broader question of political organisation. If exchange networks were managed by merchant groups operating independently of any centralised political authority, the IVC's commercial integration would represent a market-like system maintained by mutual interest rather than by state coercion. If, by contrast, exchange was coordinated through administrative mechanisms — whether located in the citadel complexes, in guild organisations, or in religious institutions — the commercial infrastructure would imply a different kind of governance even without palatial architecture of the Mesopotamian type. The seal-and-sealing system, which represents the most tangible surviving trace of IVC administrative practice, is consistent with both interpretations: seals can function as personal or institutional identity markers in either a market or an administrative context, and the evidence does not currently permit a definitive choice between these models.

Chapter 38

The cart figurines, alongside the

boat motifs incised on a small number of seals and the documented use of riverine transport along the Indus trunk stream, indicate a transport infrastructure combining overland bullock-cart movement for short- and medium-distance bulk transport with river and coastal shipping for the long-distance trade documented in

Chapter 39

33.2 The Dockyard Question at Lothal

Proposition MC.4: The Lothal Basin — Tidal Dock or Irrigation Reservoir. The large brick-lined rectangular basin at Lothal, excavated by S.R. Rao and originally interpreted as a tidal dockyard connecting the settlement to the Gulf of Khambhat via a now-silted channel, has been the subject of a long-running reinterpretation debate: Leshnik (1968) and subsequent critics have argued that the basin's dimensions, the absence of clear ship-related material culture (bollards, anchors of unambiguous type) in direct association, and the basin's better fit to irrigation-reservoir engineering parameters make a freshwater storage or irrigation function at least as plausible as a maritime dock. Rao and later defenders of the dock hypothesis (Possehl, among others) point to the basin's proximity to a contemporary channel with documented tidal influence and to Lothal's well-attested role as a coastal trade node (the site has produced a Persian Gulf-style seal and other exchange-network material) as supporting the original interpretation. The dispute remains unresolved in the published literature, and this volume does not adjudicate it; it is presented here as a representative example of how even physically well-preserved IVC structures can resist confident functional interpretation in the absence of textual confirmation, a methodological caution that recurs throughout the present account's treatment of the IVC's material record.

Chapter 40

Textile Production and the Organic-Evidence Gap

40.1 Indirect Evidence for a Major but Poorly Preserved Industry

Definition MC.2: The Spindle Whorl and Impression Evidence Base. Direct textile remains from IVC sites are exceptionally rare, a consequence of the same organic-preservation bias discussed in Proposition WHL.1, surviving in only a handful of mineralised or carbonised fragments (notably at Mohenjo-daro and a small number of other sites). The bulk of evidence for Harappan textile production is accordingly indirect: large numbers of terracotta and faience spindle whorls across virtually every excavated Mature Harappan settlement, attesting widespread spinning activity; impressions of woven cloth preserved as casts on the undersides of some sealed clay packages and on a small number of corroded metal objects against which textile had been pressed at the time of burial; and occasional dye-vat-like installations interpreted, with the usual functional-ambiguity caveats already developed for the Kalibangan fire-pit case (Case Study REL.1), as possible textile-dyeing

facilities. **Finding MC.2: Cotton and the IVC's Possible Priority. Mineralised cotton fibre evidence** from Mohenjo-daro, alongside cotton seed evidence from the archaeobotanical record dis- cussed in Chapter 21, has led some textile historians (Gulati & Turner 1929, in early founda- tional work; more recent archaeobotanical syntheses) to credit the IVC with among the earli- est attested cotton cultivation and spinning anywhere in the world, predating well-documented cotton textile production in Mesopotamia and Egypt by a significant margin. This claim, while resting on a genuinely small number of preserved specimens, is less contested than many of this volume's other priority claims because cotton fibre identification under mi- croscopy is a comparatively low-ambiguity determination relative to, for instance, iconographic or script-sign interpretation, illustrating that not every evidentiary domain in IVC studies suf- fers equally from the interpretive ambiguity emphasised elsewhere in this volume; some cat- egories of physical evidence, cotton fibre identification among them, support comparatively high-confidence Tier 1 conclusions even from a small sample.

40.2 Dyeing and Colour Technology

Case Study MC.2: Madder and the Chanhu-daro Dye Vats. Excavated installations at Chanhu- daro interpreted as dye-vats, in conjunction with botanical evidence for madder (Rubia species, a red dye source) cultivation or trade, suggest that the Harappan textile industry included a dedicated dyeing stage producing the kind of red-dyed cloth that later historical South Asian textile traditions, and the broader Indian Ocean dyed-cotton trade of the historical and early modern periods, would make into one of the subcontinent's most

significant and continuous craft export industries — a continuity of craft tradition, if not of any specific demonstrable unbroken production lineage, that parallels the bullock-cart continuity noted in Definition WHL.1 and underscores a broader theme of this synthesis: certain elements of South Asian material culture exhibit a striking long-term continuity of basic form and technique across the multi-millennial gap separating the Harappan period from the present, even where the specific cultural, linguistic, and political continuity of the populations involved remains, as Part II's linguistic and genomic evidence has shown, considerably less certain.

The near-total absence of preserved textiles from IVC contexts is an evidentiary problem of the first order. Cotton cultivation is attested by carbonised seeds and mineralised fibres recovered from a copper object at Mohenjo-daro — the earliest secure evidence for cotton anywhere in the world. Spindle whorls of terracotta and faience are among the most common small finds across IVC sites, implying spinning activity at a scale consistent with organised production. The extraordinary regularity of spindle whorl dimensions at some sites suggests standardised thread weights for specific textile types. Loom weights are less common than in contemporary Levantine contexts, possibly reflecting the use of a backstrap loom that leaves fewer traces. Indirect evidence comes from Mesopotamian cuneiform documents referring to Meluhha goods: several passages appear to reference textiles among the imports, though the translations are disputed. The combination of early cotton cultivation, abundant spinning equipment, and external textual references points to textile production as a likely major component of IVC output and long-distance trade, even though the actual fabrics remain almost entirely invisible to archaeology. The recovery of impressions of woven fabric on the undersides of certain clay sealings provides occasional glimpses of textile technology that strengthen the inference of a sophisticated weaving industry operating at scale across multiple IVC urban centres.

Chapter 41

Boat Technology and Riverine-Maritime Transport

41.1 The Indirect Evidence for Harappan Watercraft

Definition MC.3: Boat Imagery and Dockyard Claims. Evidence for Harappan watercraft is, like the textile evidence of Chapter 34, almost entirely indirect: incised and painted boat depictions on a small number of seals, sealings, and potsherds, showing flat-bottomed, single-masted vessels broadly consistent with riverine and coastal cargo-carrying craft rather than deep-sea vessels; and the much-debated Lothal "dockyard," a large rectangular brick-lined basin originally interpreted by its excavator (S.R. Rao) as a tidal dock for maritime vessels, an interpretation subsequently challenged by some scholars (Leshnik 1968) who argue the basin's dimensions, lack of unambiguous mooring or channel features, and inland hydrological setting are equally consistent with a large irrigation or water-storage reservoir of the kind documented at Dholavira (Case Study GEO.1), without invoking any maritime function at all. **Finding MC.3: An Unresolved Functional Debate With Real Stakes for** the Trade Picture. The Lothal dockyard debate matters beyond its narrow archaeological interest because a confirmed maritime dockyard would provide direct infrastructural corroboration for the seal and bead evidence of long-distance Gulf trade (Chapters 83 and 42), strengthening the case for organised, large-scale Harappan maritime shipping capacity rather than trade conducted via

smaller-scale riverine transport supplemented by Gulf-side intermediary vessels. In the continued absence of a definitive resolution, this volume treats the maritime-dockyard interpretation as a plausible but unproven Tier 2 hypothesis, with the trade relationship it- self remaining well established on independent seal and bead evidence regardless of which specific transport infrastructure interpretation of the Lothal basin ultimately prevails.

The cuneiform evidence for Meluhha trade provides the most direct external documentation of IVC maritime activity. Several texts from the Ur III and Old Babylonian periods mention Meluhha ships, Meluhha wood, Meluhha stone, and Meluhha animals — including what appear to be references to Indian domesticated animals transported to Mesopotamia. The identification of Meluhha with the IVC is supported by the geographic, chronological, and commodity correspondences, though the identification is not universally accepted and the term may have had a shifting geographic referent across different periods. The Mesopotamian documentation of maritime trade with Meluhha implies a sustained commercial relationship involving the construction and operation of seagoing vessels capable of crossing the Arabian Sea — a maritime technology whose South Asian component is largely invisible in the IVC archaeological record but whose existence is a necessary inference from the Mesopotamian textual evidence.

Chapter 42

Seal Iconography Beyond the Unicorn: A Survey of Animal

Motifs

42.1 The Statistical Dominance of the "Unicorn" Motif and What It Might Mean

Among the recurring animal motifs depicted on Harappan seals, the so-called "unicorn" — a profile-view depiction of a bovine-like animal with a single forward-projecting horn, almost certainly a stylised convention for depicting a horned animal in profile rather than a depiction of any real single-horned creature — is by a substantial margin the most frequent motif in the surviving seal corpus, appearing on a clear majority of figurative seals at most major sites. This statistical dominance has prompted speculation that the unicorn motif carried some spe- cific clan, lineage, or institutional ailiation significance, possibly functioning analogously to a heraldic device or guild emblem, though this interpretation remains a plausible infer- ence rather than a demonstrated finding, given that the seal corpus's brief format (Definition SEAL.1) provides no accompanying textual confirmation of any such institutional reading. Other recurring motifs — the humped zebu bull, the elephant, the tiger, the rhinoceros, and a smaller number of composite or therianthropic (part-human, part-animal) figures connected to the iconographic discussion of Chapter 54 — occur with markedly lower frequency than the unicorn motif, and the resulting statistical distribution (a small number of highly frequent motifs alongside a longer tail of rare ones) is itself a data point relevant to the broader question of whether seal ownership and use was organised around a relatively small number of major social or institutional categories (consistent with the unicorn motif's domi- nance reflecting a single very large ailiation category) or a larger number of smaller, more fragmented groupings, a question that intersects with, but does not resolve, the state-versus- heterarchy debate of

The absence of narrative or mythological scenes in the Indus seal corpus — in contrast to the rich narrative iconography of Mesopotamian and Egyptian glyptic — represents a significant constraint on interpretation. Without narrative context, it is impossible to determine whether the animal and hybrid figures on seals represent deities, spirits, clan emblems, or commodity categories, and attempts to read narrative meaning into single-figure compositions risk importing assumptions from iconographic traditions that may have had entirely different organisational principles. The standardisation of the unicorn-before-standard motif across thousands of seals from geographically dispersed sites argues for a fixed, conventional meaning that was broadly shared across the IVC system, but the nature of that meaning re-

mains opaque.

Chapter 43

Personal Ornamentation and Status Signalling

43.1 Bangles, Beads, and the Material Markers of Social Position

Beyond the long carnelian beads discussed in Chapter 83 as primarily an export commodity, the IVC's broader personal-ornamentation record — shell, terracotta, faience, and metal bangles; steatite and faience beads in a wide range of shapes and sizes; and a smaller number of gold and silver ornaments concentrated at a handful of sites — provides a further line of evidence bearing on the question of social differentiation addressed more directly through mortuary evidence in

The social significance of personal ornament in the IVC extended beyond individual adornment to encompass interregional signalling of identity and affiliation. The distribution of specific ornament types — particular bead shapes, specific shell bangle forms, distinctive faience designs — across sites separated by hundreds of kilometres suggests that ornamental repertoires functioned as markers of participation in the broader IVC exchange network and possibly of membership in specific social or professional groups whose identity was expressed through shared material vocabularies. The export of carnelian beads to Mesopotamia, where they appear in elite mortuary contexts, indicates that IVC ornamental objects carried prestige value across cultural boundaries, a form of interregional prestige exchange that is well documented in comparative Bronze Age archaeology and that provided both economic incentive and social infrastructure for the maintenance of long-distance commercial relationships.

Chapter 44

The general

pattern across excavated assemblages is one of relatively modest differentiation: while gold and silver ornaments do occur and are un- evenly distributed, they are not concentrated in the kind of strikingly wealth-differentiated burial or hoard contexts that would indicate a sharply stratified elite comparable to, for in- stance, the Royal Cemetery of Ur's gold-rich Mesopotamian royal burials. This relative mod- esty of ornamentation-based status differentiation is broadly consistent with, and reinforces, the low-monumentality and modest-mortuary-differentiation evidence discussed elsewhere in this volume as part of the cumulative case for a heterarchical rather than sharply stratified- monarchical social structure (Definition OQ.1), though as with that broader synthesis, this conclusion should be treated as

the current best reading of an incomplete evidentiary picture rather than a definitively closed question.

The mortuary evidence from the IVC raises important questions about the relationship between burial practice and social organisation that the existing data cannot fully resolve. The relatively modest differential in grave wealth observed at IVC cemeteries, compared to the sharp gradients visible in contemporaneous Mesopotamian royal burials or in the kurgan burials of the Eurasian steppes, is consistent with the heterarchical model of IVC political organisation but does not prove it: mortuary practice is only one of many dimensions on which social stratification is expressed, and the IVC's social hierarchy may have been expressed primarily through access to craft goods, residential space, and exchange networks rather than through funerary display. The systematic comparison of residential architecture and domestic assemblages across different areas of the same IVC urban site — a form of analysis that has been applied at Harappa by the Harappa Archaeological Research Project — offers a complementary approach to the question of social differentiation that is less dependent on the fragmentary mortuary record.

Chapter 45

Urbanism Without Monumentality: The IVC Against

Mesopotamia and Egypt

45.1 Three Bronze Age Urban Trajectories

The IVC's chronological window (Chapter 9) overlaps substantially with the Old Kingdom and early Middle Kingdom in Egypt and with the Early Dynastic through Old Babylonian periods in Mesopotamia, making a structured comparison of the three urban trajectories a natural check on what is and is not distinctive about the Harappan case. **Definition CC.1: The Monumentality Gradient.** Egypt and Mesopotamia, across the rel- evant period, produced an archaeologically unambiguous and textually documented appara- tus of centralised rule: royal tombs of staggering material investment (the Giza pyramids, the royal cemetery of Ur), monumental temple complexes dedicated by name to specific deities and maintained by documented temple economies, palace structures distinguishable from ordinary domestic architecture by scale and decorative programme, and royal inscriptions naming individual rulers, their conquests, and their genealogies. The IVC, across more than a century of excavation at its largest sites, has produced none of these categories of evidence in an unambiguous form: no structure has been confidently identified as a royal palace, no indi- vidual ruler's name is known (the undeciphered script in principle could contain such names, but no inscription has been read), no royal tomb or elite mortuary assemblage approaching Mesopotamian or Egyptian scale has been recovered, and no temple complex with confirmed cultic dedication has been identified, the Great Bath of Note MC.1 being the closest candidate and remaining functionally ambiguous. Finding CC.1: The Gap Is Not an Artefact of Incomplete Excavation. The monumental- ity gap cannot be straightforwardly attributed to incomplete archaeological coverage: Mohenjo- daro and Harappa have each been subject to more than a century of excavation, including ex- tensive citadel-mound exposure where elite and administrative structures would be expected on the Mesopotamian and Egyptian comparative model, and the absence of a clear palace or royal tomb in these extensively excavated zones is a positive finding rather than simply an absence of evidence. This does not mean such structures never existed — Mohenjo-daro's lower strata remain inaccessible because of a risen water table, and erosion has removed an unknown fraction of the uppermost occupation levels at several sites — but the degree of excavation achieved is suicient that the monumentality gap is treated by most specialists (Possehl, Kenoyer, Wright) as a genuine feature of Harappan civilisation requiring explana- tion, not merely a sampling artefact.

45.2 Competing Explanations

Proposition CC.1: Three Non-Exclusive Explanatory Families. The monumentality gap has attracted three broad classes of explanation, which are not mutually exclusive and may each capture part of the picture. The ideological-egalitarian explanation (most associated with Pos- sehl and, in a more developed theoretical form, with Miller's analysis of the weight-standardisation evidence) holds that Harappan elites, whatever their existence, deliberately eschewed the dis- play vocabulary of monumental self-glorification favoured by Mesopotamian and Egyptian rulers, channelling surplus instead into civic infrastructure (drainage, standard-ised weights) and craft production rather than into

royal display. The decentralised-heterarchy explanation (developed most fully by Pos-sehl and taken up in the state-question debate of Chapter 39) holds that the IVC's political organisation was genuinely less centralised than the Mesopotamian city-state or Egyptian territorial-kingdom model, distributing authority across multiple insti- tutions (merchant guilds, craft associations, perhaps religious bodies) rather than concentrat- ing it in a sin-gle ruling lineage with the resources and motive to build self-glorifying monu- ments. The taphonomic-loss explanation holds that monumental structures did exist but have been dis-proportionately destroyed by the same riverine processes (channel migration, alluvi- ation, the Indus's documented tendency to shift course) that have complicated the chronological and settlement-pattern reconstructions discussed throughout this volume, and that the sur-viving sample is therefore biased against precisely the structures comparison with Egypt and Mesopotamia would lead one to expect.

Chapter 46

The Heterarchy Debate: Was the IVC a State?

46.1 Defining the Terms

Definition CC.2: State, Heterarchy, and the Archaeological Operationalisation Problem In the comparative-anthropological literature, a state is conventionally defined by some combination of: a centralised, hierarchically organised governing apparatus with a monopoly (or near-monopoly) on legitimate coercive force; specialised administrative personnel distinct from kin-based or community leadership; and the capacity to extract and redistribute surplus through taxation or tribute. Heterarchy, a term introduced into archaeological theory by Crumley (1995) and applied to the IVC specifically by Pos- sehl and later theorists, denotes a form of social-political organisation in which power is distributed across multiple, functionally differentiated institutions (for instance craftspecialist guilds, merchant associations, and ritual authorities) that may compete or co- operate without any one of them holding the comprehensive coercive and administrative authority that the state definition requires. The operationalisation problem is that both models generate broadly compatible archaeological expectations under the IVC's specific preservation conditions: a heterarchical confederation of guilds enforcing shared weight and brick standards through merchant consensus could in principle produce a material signature similar to a centralised state enforcing the same standards through adminis- trative fiat, and the script's undeciphered status (Part II) removes the textual evidence that would normally discriminate between these models in a Mesopotamian or Egyptian context. **Finding CC.2: The Absence of Documented Warfare as Indirect Evidence. A further datum bearing on** the state-question debate is the comparatively low frequency, relative to contemporary Mesopotamia, of unambiguous evidence for organised inter-polity warfare within the IVC's territory: city walls at IVC sites are now generally interpreted (following reassessment by Possehl and others) as flood-control and prestige structures rather than pri- marily defensive fortifications, weapons proper (as opposed to tools with potential dual use) are a minor component of the metal-artefact assemblage relative to Mesopotamian compara- nda, and skeletal trauma studies (most relevant at Mohenjodaro, where Dales (1964) de- cisively reassessed the earlier "massacre" interpretation discussed in Chapter 47) have not produced a clear signature of organised lethal violence comparable to that documented at several Mesopotamian sites. This pattern is consistent with, though it does not require, a political organisation in which the coercive apparatus characteristic of competing territorial states was less developed or less archaeologically visible than in Mesopotamia — an absenceof-evidence finding that must be weighed with appropriate caution given the general inter- pretive

diiculties the IVC's material record presents throughout this study.

The absence of palatial architecture, royal tombs, and centralised storage facilities of Mesopotamian scale has led many scholars to conclude that the IVC lacked a state in the conventional sense. Possehl (2002) proposed the concept of a Faceless Indus State, emphasising the paradox of evident large-scale coordination without identifiable coordinators. An alternative framework draws on the heterarchy concept: power distributed across multiple, non-ranked institutions rather than concentrated in a single apex. Craft guilds, merchant associations, priestly bodies, and neighbourhood councils may each have exercised domain-specific authority without any single institution subordinating the others. Kenoyer (1997) argued that control over the standardised weight system, the seal production network, and access to prestige raw materials constituted a dispersed form of economic governance that did not require concentrated coercive power. The uniformity of brick ratios, street orientations, and drainage systems across hundreds of kilometres is consistent with shared institutional norms rather than top-down imposition, though distinguishing between these mechanisms archaeologically is difficult. The heterarchy model remains heuristically productive precisely because it refuses to project familiar state structures onto evidence that does not require them, though it faces the challenge of specifying the actual mechanisms by which heterarchical coordination was achieved and maintained across the scale and geographic extent of the IVC system, which substantially exceeds that of most historically documented heterarchies.

Chapter 47

Writing Systems Compared: Why Some Scripts Get

Deciphered

47.1 A Comparative Decipherment Typology

Definition CC.3: The Three Necessary Conditions for Decipherment. Drawing on the com- parative history of script decipherment (Linear B, Egyptian hieroglyphs, cuneiform, Mayan glyphs, and the unresolved cases of Linear A, Proto-Elamite, and Rongorongo), historians of decipherment (most systematically Robinson, 2002) have identified three conditions whose joint satisfaction has, without exception, preceded every successful decipherment of an an- cient script: (i) a suicient corpus of text, generally numbering in the thousands of running signs at minimum; (ii) either a bilingual text pairing the unknown script with a known lan- guage (the Rosetta Stone for Egyptian, bilingual cuneiform-Old Persian inscriptions for Akka- dian) or strong independent grounds for assigning the underlying language family with confi- dence (as Michael Ventris did for Linear B, working from internal structural clues toward an early-Greek hypothesis before full confirmation); and (iii) a plausible phonological bridge, typi- cally supplied by known proper names (royal names in cartouches for Egyptian, place names for Linear B) whose pronunciation could be independently inferred and matched against sign sequences. The Indus corpus, as established in Chapter 5, fails condition (i) by roughly two orders of magnitude, lacks any candidate for condition (ii), and lacks the secure languagefamily assignment that would substitute for it, and condition (iii) is correspondingly inacces- sible since no proper name can be confirmed without already having solved (i) or (ii). Case Study CC.1: Linear A — A Cautionary Parallel. Linear A, the undeciphered script of Minoan Crete (in use roughly 1800–1450 BCE), presents a structurally similar problem to the Indus script: a moderate corpus (larger than the Indus corpus but still small by decipherment standards, numbering in the low thousands of signs), no confirmed bilingual, and a contested language-family assignment, with proposals ranging from a non-Indo-European Aegean substrate language to Luwian-related Anatolian hypotheses, none commanding consensus. Linear A's partial phonetic decipherment was achieved only indirectly, by extrapolating syllabic values backward from the related and successfully deciphered Linear B script (which shares many sign-forms with Linear A but encodes Mycenaean Greek), a bootstrapping strategy with no available analogue for the Indus script, since no later script descended from or closely related to the Indus sign system has been identified with the confidence that the Linear A-to-Linear B relationship commands. Linear A's seven decades of partial, contested, language-unknown decipherment — readable phonetically in places, uninterpretable as language — is arguably the closest real-world analogue to where Indus decipherment ef-

forts plausibly could arrive even in an optimistic scenario, and the comparison tempers any expectation of a full Indus decipherment as opposed to the kind of partial structural decipherment that computational methods (Part IV) have in fact delivered.

47.2 Proto-Elamite and Rongorongo: Two Further Failures

Note CC.1: What the Persistent Failures Have in Common. Proto-Elamite (used in southwestern Iran circa 3100–2900 BCE, with a substantial corpus of) and Rongorongo (the script of Easter Island, with a corpus of fewer than thirty surviving inscribed objects) both remain undeciphered despite, in the Proto-Elamite case, a corpus considerably larger than the Indus corpus and despite the existence of a known successor administrative tradition (proto-Elamite numerical notation has been partially read,

but the accompanying sign system that is presumed to encode language has resisted decipherment). The common thread across all of these unresolved cases — Indus, Linear A, Proto-Elamite, Rongorongo — is the absence of condition (ii) from **Definition CC.3: none possesses a bilingual text** or an external phonological anchor, and corpus size alone, even where it is not the limiting factor as in the Proto-Elamite case, has proven insuicient to substitute for it. This comparative pat- tern is the strongest available evidence for the structural diagnosis of Chapter 17: the Indus script's resistance to decipherment is not an anomaly explained by some specific deficiency of method or effort, but an instance of a well-documented general pattern governing which ancient scripts can and cannot be read. approximately 1,600 tablets

Chapter 48

Violence, Fortification, and the Question of Indus Warfare

48.1 Reassessing the City Walls

Definition CC.4: Functional Ambiguity in Harappan Perimeter Walls. The substantial brick and mud-brick perimeter walls enclosing the citadel mounds (and, at some sites, portions of the lower town) at Mohenjo-daro, Harappa, Kalibangan, and Dholavira were interpreted by early excavators (working within a culture-historical paradigm shaped by contemporary Near Eastern fortification archaeology) as primarily defensive military fortifications. Subse- quent reassessment has emphasised three competing or complementary functions that the same physical structures could serve: flood control (raising the citadel above seasonal Indus and Ghaggar-Hakra inundation, consistent with the river-system hazards discussed in Chap- ter 20), control of access for administrative or toll purposes (regulating the movement of goods and people into the elevated precinct without implying military threat), and prestige display (monumental walls as a marker of civic investment and status, independent of any actual defensive function). The walls' construction — generally lacking the parapets, projecting bastions optimised for enfilading fire, and other features that distinguish purpose-built military fortification in the well-documented Mesopotamian and Near Eastern comparative record — is more consistent with the flood-control and access-control functions than with a primarily military one, though the three functions are not mutually exclusive and a single wall could serve all three simultaneously.

48.2 The Weapons Assemblage

Proposition CC.2: A Comparatively Modest Weapons Signature. The metal artefact assemblage from IVC sites includes objects with potential dual use as tools or weapons — bronze and copper spearheads, axes, and a small number of dagger-like blades — but lacks the spe- cialised, mass-produced military equipment (standardised sword forms, the chariot-associated weaponry of the later Bronze Age, fortification-breaching siege equipment) that characterises the contemporary Mesopotamian and, somewhat later, Egyptian and Near Eastern military archaeological record. Quantitatively, weapons and weapon-like objects form a small mi- nority of the IVC metal corpus relative to tools, ornaments, and vessels, a pattern noted by multiple specialists (Possehl, Kenoyer) as consistent with, though again not conclusive proof of, a society in which organised inter-group lethal violence played a comparatively minor role relative to its Bronze Age contemporaries — a finding that, combined with Finding CC.2, forms part of the broader "peaceable Harappan" characterisation common in the specialist literature, while falling short of establishing that interpersonal and small-scale violence

was entirely absent, a distinct question addressed through skeletal evidence in

The IVC presents a remarkably muted signature of organised violence relative to contemporary urban civilisations. Fortification walls at Dholavira and Kalibangan have been identified, but their scale is more consistent with flood control or administrative demarcation than with military defence against human attackers. Weapons are present in the material record but in quantities that do not distinguish them clearly from hunting or craft tools. The absence of a dedicated warrior class, inferred from the lack of warrior burials with weapons assemblages of the kind familiar from Yamnaya or early Bronze Age European contexts, is notable. Mass graves showing evidence of perimortem trauma at the scale of documented ancient massacres are absent from the IVC record. The Wheeler-era massacre victims at Mohenjodaro have been comprehensively reanalysed and represent deaths distributed across multiple episodes rather than a single violent event. Inter-site conflict finds no clear archaeological signature during the Mature Harappan phase. Whether this reflects genuine low levels of organised violence, the operation of conflict-resolution mechanisms archaeologically invisible, or simply the incompleteness of excavation is impossible to determine. The contrast with post-IVC cemetery evidence, which shows elevated trauma frequencies in some Late Harappan populations, may suggest that the Mature phase's apparent peaceability was a function of specific political conditions that dissolved during the decline, though this inference requires confirmation from a larger skeletal sample than is currently available from well-documented Late Harappan burial contexts.

Chapter 49

Comparative

Mesopotamia, and the Gulf
Trade-Network
Integration:
The
IVC,

49.1 Asymmetric Documentation of a Bilateral Relationship

Definition CMP.1: A Textually Asymmetric Trade Relationship The IVC-Mesopotamia trade relationship documented through the Meluhha textual references (Chapter 31) and the bead and seal material evidence (Chapters 83 and 25) is asymmetric in its surviving documentation: Mesopotamian cuneiform sources describe and name the trading partner (Meluhha), its intermediary (Dilmun, generally identified with Bahrain), and in some texts specific traded commodities and the activities of named Mesopotamian merchants engaged in the trade, while no comparable named Indus-side textual description of the relationship survives, both because the Indus script remains undeciphered and because, even if it were read, the seal-and-sealing corpus's brief la- bel format (Definition SEAL.1) is unlikely to contain narrative trade descriptions of the kind found in Mesopotamian administrative archives. This asymmetry means that the documented relationship is necessarily described, in the existing scholarly literature, sub- stantially through Mesopotamian eyes, a one-sided perspective problem directly analo- gous to, though evidentially distinct from, the script-decipherment asymmetry discussed throughout Part IV. **Proposition CMP.1: Correcting for the Mesopotamian-Centric Documentary Bias. This volume's** treatment of IVC-Mesopotamia trade attempts, where possible, to centre Indus-side archaeological evidence (the bead and seal export corpus, the standardised weight system implying an Indus-side metrological framework for trade transactions, Definition NUM.1) rather than relying solely on Mesopotamian textual framing, in order to partially correct for the asymmetry of Definition CMP.1, while acknowledging that this correction remains structurally limited: archaeological material evidence can establish that trade occurred and estimate its rough commodity composition, but it cannot recover the kind of first-person in- stitutional or individual perspective on the relationship that the cuneiform textual record, however one-sided, does preserve for the Mesopotamian side.

The absence of cuneiform-style administrative records from the IVC is a fundamental asymmetry in the comparative evidence that cannot be wished away by invoking the possibility of perishable media. Even if IVC administrators recorded transactions on palm leaves or wooden tablets, the near-total absence of clay impression evidence for extensive accounting — of the kind that Mesopotamian accountants routinely created as a byproduct of administrative practice — is itself informative. It suggests either that the scale and intensity

of administrative recording was substantially lower in the IVC than in Mesopotamia, or that the IVC employed administrative technologies so different from the clay tablet tradition that they leave no comparable archaeological signature. The former possibility is consistent with a more decentralised exchange system; the latter remains speculative without positive evidence.

Chapter 50

Comparative Collapse Dynamics: The IVC Alongside Other

Bronze Age Decline Episodes

50.1 The Late Bronze Age Collapse as a Partial Analogy

Case Study CMP.1: Comparing the IVC Decline to the c. 1200 BCE Eastern Mediterranean Collapse. The eastern Mediterranean Late Bronze Age collapse (c. 1200 BCE), affecting Mycenaean Greece, the Hittite Empire, and contributing to broader regional disruption across the Levant, is sometimes invoked as a comparative case for understanding civilisational collapse dynamics generally, and by extension for the IVC's own decline (Chapter 10 and the synthesis of Chapter 87). The comparison is instructive but limited: the eastern Mediterranean collapse is associated with a documented (if still debated in its specific causal weighting) combination of factors including possible "Sea Peoples" disruption, earthquake clustering, and climate stress, operating on a comparatively compressed multi-decade timescale, in contrast with the IVC's more gradual two-to-three-century transformation process (Definition OQ.2). The differing tempo between the two cases cautions against importing a generalised "collapse" model from one Bronze Age context to the other without independently verifying that the same causal tempo and mechanism applies, reinforcing this volume's preference, established in Proposition OQ.1, for describing the IVC's trajectory as a transformation rather than a collapse in the Eastern Mediterranean sense.

The specificity of the IVC's collapse trajectory — gradual deurbanisation rather than abrupt political collapse — distinguishes it from the Akkadian case while aligning it more closely with the patterns observed in other Bronze Age systems where climatic stress interacted with distributed rather than centralised political organisation. The Akkadian Empire's sudden collapse, associated with the 4.2 ka event in some accounts, reflects the vulnerability of a highly centralised political system whose administrative infrastructure depended on the maintenance of agricultural surplus in a relatively narrow geographic zone. The IVC's apparently more distributed governance, if the heterarchical model is correct, may have provided greater resilience to localised environmental stress while being vulnerable to the longer-term deterioration of the hydrological regime on which the entire system depended.

Chapter 51

The Question of Indus Influence on Later South Asian

Urbanism

51.1 Did Harappan Urban Planning Leave a Direct Legacy?

A natural question, given the sophistication of Harappan urban planning documented in Chapter 28, is whether this planning tradition left any direct technical legacy in the much later urban developments of historical South Asia, after the roughly thousand-year gap separating the end of Mature Harappan urbanism from the rise of the Mauryan-period cities of the mid-first millennium BCE. The honest answer, on current evidence, is that no clear continuous transmission can be demonstrated. Mauryan and subsequent historical South Asian urban centres show their own distinct planning conventions, generally without the specific grid-orientation, standardised-brick, and covered-drain features that define the Harappan urban package, and the intervening Late Harappan and post-Harappan periods show, if anything, a marked de-urbanisation and loss of the specific civic-infrastructure techniques discussed in Part VII rather than their gradual transmission forward. This absence of demonstrable technical continuity is itself informative: it suggests that Harappan urban planning expertise was a specific, historically contingent achievement of that particular civilisational moment, dependent on social and economic conditions (large- scale craft specialisation, long-distance trade integration, whatever administrative coordina- tion produced the standardisation discussed throughout this volume) that did not persist through the transformation discussed in Chapter 87, rather than being a permanent technical inheritance simply waiting to be rediscovered by later South Asian urban planners working from an unbroken tradition. Where later South Asian urbanism resembles the Harappan pattern, the resemblance is better explained by independent local adaptation to broadly similar environmental and economic constraints than by direct technical inheritance, a conclusion that parallels this synthesis's general scepticism, developed across Part II's linguistic and ge- nomic evidence, toward strong continuity claims unsupported by direct demonstrable trans- mission.

The methodological distinction between cultural continuity and population continuity is essential for interpreting the evidence of IVC legacy in historical South Asia. Genetic data from Narasimhan et al. (2019) demonstrate that IVC-related ancestry is a major component of all present-day South Asian genomes, establishing biological continuity in the broadest sense. But biological continuity does not entail cultural continuity in any specific domain: descendants of IVC populations may have adopted entirely new material, linguistic, and religious traditions while retaining the genomic signature of IVC ancestry. Conversely, specific cultural practices may persist through processes of diffusion or adoption that are indepen-

dent of the genetic contribution of their originators. Disentangling these processes in the South Asian context requires domain-specific evidence that traces specific practices — rather than populations in general — through the stratigraphic and textual record.

Chapter 52

A Note on Absolute Chronology and Radiocarbon Calibration

Uncertainty

52.1 Why the Dates in This Volume Carry Wider Error Bars Than They May Appear

To Throughout this volume, dates for IVC phases and events (the Mature Harappan period's conventional 2600–1900 BCE bracket, the 4.2 ka event, individual site occupation spans) have generally been given as point estimates or narrow ranges for readability, but readers should bear in mind that all such dates ultimately derive from radiocarbon measurements subject to calibration-curve uncertainty, sample-context uncertainty (whether a dated sample is securely associated with the event or phase it is taken to represent), and the inherent statistical spread of radiocarbon dating itself, which typically yields a calibrated probability range of one to several centuries at standard confidence levels rather than a precise calendar year. Where this volume's text gives a specific year or narrow range, that figure should be understood as a convenient summary of a probability distribution rather than as a precisely known calendar date, a caveat that applies with particular force to the more contested chronological questions discussed in the climate and decline chapters, where the precise dating of the 4.2 ka event's regional onset relative to the observed archaeological transformation is itself a live area of ongoing refinement rather than a settled figure.

The calibration uncertainty that affects IVC radiocarbon dating is not unique to this civilisation but is particularly consequential here because of the tight temporal coincidence between the proposed climate event (4.2 ka), the decline of the IVC urban phase, and the proposed entry of Steppe-ancestry populations — all of which are dated by different methods with different error structures. Bayesian modelling that jointly constrains radiocarbon dates, palaeoclimate proxy ages, and genomic dating estimates offers the most rigorous path toward resolving these overlapping uncertainties, but such joint modelling requires the coordinated release of data across subdisciplines that has not yet been systematically achieved for the South Asian Bronze Age.

Chapter 53

Discovery: Banerji, Sahni, and the 1924 Announcement

53.1 Two Independent Excavations Converge

Definition HI.1: The Twin Discoveries. The IVC was identified as a distinct, previously unrecognised civilisation through the convergence of two excavations conducted independently under the Archaeological Survey of India: Daya Ram Sahni's excavations at Harappa (Pun- jab), begun in 1920 following decades of the site's use as a source of ballast brick for railway construction — a destructive process that had already removed an unknown but substantial fraction of the upper occupation levels before systematic excavation began — and Rakhal Das Banerji's excavations at Mohenjo-daro (Sindh), begun in 1922 after Banerji recognised that a Buddhist stupa mound at the site overlay much older occupation strata containing seals stylistically similar to material Sahni was simultaneously recovering at Harappa. The recognition that these were not merely two similar sites but representatives of a single, previously unknown civilisation of Bronze Age antiquity was consolidated by John Marshall, then Director-General of the Archaeological Survey of India, who announced the discovery to the international scholarly community in a 1924 article in the Illustrated London News. **Finding HI.1: An Immediate Recalibration of South Asian Prehistory. Marshall's an- nouncement was received** by the international archaeological community as a major revi- sion of South Asian chronology: prior to 1924, no securely dated evidence existed for ur- ban civilisation in the subcontinent earlier than the first millennium BCE, and the Harap- pan discovery pushed back the demonstrable horizon of South Asian urbanism by some two thousand years at a stroke, placing it squarely within the same Bronze Age horizon as Egypt and Mesopotamia. Sir Flinders Petrie and other contemporary Near Eastern specialists, on viewing the Harappan seals, immediately recognised stylistic and material parallels to arte- facts recovered from Mesopotamian and Gulf contexts (a perception later vindicated by the Meluhha identification of Definition MC.4), correctly inferring an economic relationship be- tween the two regions decades before that relationship could be documented through the more rigorous evidence reviewed in

The 1924 announcement by John Marshall in the Illustrated London News framed the public reception of the IVC discovery in ways that proved durable. Marshall's rhetoric emphasised the antiquity of Indian civilisation, implicitly challenging colonial narratives of South Asian cultural stagnation, and drew comparisons to Sumer and Egypt that positioned the IVC within a competitive hierarchy of ancient cultures. The political context was not incidental: the Indian independence movement was gathering momentum, and the demonstration of a pre-Aryan urban civilisation of comparable antiquity carried obvious nationalist resonance, though Marshall himself was a British colonial official. Banerji's initial identification of the

Mohenjo-daro site had been made in 1919–1920, and Sahni's work at Harappa had produced significant finds by 1921–1922; the 1924 announcement thus reflected a consolidation of evidence accumulated over several field seasons. The decision to announce simultaneously to a popular audience and to the professional community through the Journal of the Royal Asiatic Society shaped the subsequent trajectory of IVC studies: it created an unusually high public profile from the outset, generating both popular fascination and the politically charged interpretive battles that have characterised the field ever since. The speed with which the discovery attracted international scholarly attention — with cuneiformists, Egyptologists, and classical archaeologists weighing in within months — established a pattern of interdisciplinary engagement with the IVC that has continued throughout the field's history.

Chapter 54

46.2 The Colonial Institutional Context

Note HI.1: Archaeology Under Colonial Administration. The discovery and earliest excavation of the IVC occurred entirely within the institutional framework of British colonial administration in India, with the Archaeological Survey of India operating under British directors-general (Marshall among them) employing, training, and in significant measure subordinating Indian archaeologists (Sahni and Banerji prominent among them) within a colonial scien- The Indus Enigma tific hierarchy. This institutional context shaped the discovery's reception in ways that bear on the political-sociology themes of Chapter 24: the new civilisation was framed, in early British scholarship, within a diffusionist paradigm that initially looked to Mesopotamian in- fluence or colonisation as a possible explanation for Harappan urbanism, a framing that the subsequent seventy years of excavation (revealing the IVC's distinctive, non-derivative ma- terial culture, discussed throughout Part I of this volume) have substantially revised, but whose echo persists in some of the diffusionist-versus-indigenist framings that recur in the politically inflected reception discussed in

Chapter 55

Wheeler, the Massacre Narrative, and Its Debunking

55.1 The 1944–1948 Excavations and a Provocative Hypothesis

Definition HI.2: Wheeler's Aryan Invasion Reading of the Mohenjo-daro Skeletons. Sir Mortimer Wheeler, Director-General of the Archaeological Survey of India from 1944, conducted further excavations at Mohenjo-daro and Harappa and, in a series of publications culminating in his 1953 synthesis The Indus Civilization, proposed an influential interpretation linking the IVC's decline to the Indo-Aryan migration: pointing to a cluster of some three dozen disarticulated human skeletons recovered from late occupation contexts at Mohenjo-daro, several showing what Wheeler read as cut-mark trauma, and invoking the Rigveda's references to the god Indra as puramdara ("fort-destroyer"), Wheeler proposed that invading Indo-Aryan ("Aryan") populations had violently overrun and massacred the city's Harappan inhabitants, providing both a causal mechanism for the IVC's collapse and an archaeological correlate for the Vedic textual tradition.

55.2 The Reassessment

Finding HI.2: Dales's Decisive Refutation. George Dales, in a influential 1964 paper pointedly titled "The Mythical Massacre at Mohenjo-Daro", demonstrated that Wheeler's massacre hypothesis did not withstand close examination of the excavation's own stratigraphic and con- textual evidence: the skeletons in question derived from multiple different stratigraphic lev- els and locations across the site rather than from a single destruction horizon, were associated with post-abandonment squatter occupation debris rather than with the city's mature urban phase, showed no consistent pattern of weapon trauma when re-examined, and in several cases were found in postures and contexts (partially articulated, in what appear to be infor- mal disposal contexts rather than battle contexts) inconsistent with sudden violent death and abandonment in place. Dales's reassessment has been accepted by virtually the entire subse- quent specialist literature (Possehl, Kenoyer, and the broader consensus reflected in Finding CC.2's treatment of the low overall violence signature), and the "Aryan invasion massacre" hypothesis is now treated in the professional archaeological literature as a textbook case of an evocative but evidentially unsupported interpretation, not as a live hypothesis. **Note HI.2: Why the** Discredited Hypothesis Still Circulates. Despite its comprehensive professional refutation more than half a century ago, the Wheeler massacre narrative continues to circulate in popular accounts, secondary-school textbook treatments in some jurisdictions, and especially in the politically charged debates discussed in Chapter 24, where it is invoked, in a further irony, by participants on both sides of the Indigenous Aryanism de-

bate — by Out-of-India proponents as a strawman example of supposedly biased "invasionist" mainstream scholarship, and occasionally, in older popular accounts, as if it remained the scholarly consensus on IVC decline. Its persistence outside the specialist literature is a useful illustrative case of the general pattern, discussed in the Introduction's tier-distinction framework, whereby a scientific claim's refutation within the specialist literature does not automatically propagate to public and political discourse on a comparable timescale.

Mortimer Wheeler's massacre narrative represents one of the most instructive case studies in archaeological over-interpretation driven by theoretical precommitment. Wheeler, whose military experience and familiarity with the Rigvedic description of Indra as a destroyer of fortresses inclined him toward violent explanations, identified articulated skeletons in the upper levels of Mohenjo-daro as massacre victims of invading Aryans. The narrative was compelling, and appeared to provide the material correlate for the Rigvedic dasyu. Dales's 1964 refutation, published in Expedition: The Magazine of the University of Pennsylvania Museum (vol. 6, no. 3), demonstrated through systematic reanalysis that the skeletal evidence was distributed across multiple stratigraphic levels spanning several centuries, showed no consistent perimortem trauma, and represented ordinary deaths rather than a massacre event. The anatomical arrangement in some cases reflected post-mortem disturbance rather than bodies left where they fell. The episode illustrates the interpretive risks created when a striking narrative achieves early canonical status: once Wheeler's massacre had entered the textbooks, it required active effort from the next generation to dislodge it, and traces of the narrative persisted in popular writing long after specialist consensus had moved on — a pattern with ongoing relevance to the field's engagement with politically motivated interpretations of a civilisation that continues to attract partisan readings.

Chapter 56

Partition and the Bifurcation of Indus Studies

56.1 A Discipline Divided by a New Border

Definition HI.3: The 1947 Discontinuity

The 1947 Partition of British India placed the IVC's two original type sites, Harappa and Mohenjo-daro, within the newly created state of Pakistan, while the Archaeological Survey of India — the institution that had conducted and continued to fund the disci- pline's foundational excavations — remained based in India, severing, at a stroke, the previously unified institutional framework for IVC research and compelling Indian ar- chaeology to develop a research programme largely independent of direct access to the civilisation's most extensively excavated and best-known sites. **Finding HI.3: A New Generation of Indian Site Discoveries, 1950s–1990s. The post- Partition decades** saw a sustained Indian archaeological programme, conducted largely inde- pendently of the Pakistani sites, that identified and excavated a substantial number of new IVC and IVC-related sites within Indian territory: Kalibangan (Rajasthan, excavated by B.B. Lal and B.K. Thapar from 1961, notable for its fire-altar evidence discussed in Chapter 55), Lothal (Gujarat, excavated by S.R. Rao from 1955, the site of the disputed dockyard of Propo- sition MC.4), Dholavira (Gujarat, excavated by R.S. Bisht from 1989, the water-management site of Case Study GEO.1), Surkotada (Gujarat, excavated by J.P. Joshi, the site of the con- tested equid remains of Note MC.2), and Rakhigarhi (Haryana, excavated from the 1990s and subject to the genomic sampling discussed in Chapter 2), among numerous smaller sites. This sustained Indian excavation programme substantially expanded the known geographic range of the IVC eastward and southward into Haryana, Rajasthan, and Gujarat, revealing the Ghaggar-Hakra settlement density discussed in Finding GEO.1 that had been largely in- visible to the pre-Partition, Indus-trunk-focused excavation record.

56.2 Pakistani Archaeology and International Collaboration

Case Study HI.1: The Harappa Archaeological Research Project. Continued excavation at the original type site of Harappa, within Pakistan, has been conducted since 1986 under the Harappa Archaeological Research Project, a sustained international collaboration directed for much of its history by Jonathan Mark Kenoyer (University of Wisconsin–Madison) and Richard Meadow (Harvard) working with Pakistani institutional partners, and has produced much of the detailed craft-production evidence (bead manufacture, drilling technology) dis-

cussed in

The 1947 partition of British India divided the IVC's known site corpus between two newly antagonistic nations. Mohenjo-daro and the majority of major Indus sites fell within Pakistani territory; Harappa also fell in Pakistan. India retained relatively few large sites, with Kalibangan, Lothal, and Ropar among the exceptions. The institutional consequences were immediate: the Archaeological Survey of India and the newly formed Department of Archaeology of Pakistan developed separate research programmes, methodological traditions, and interpretive frameworks, with limited collaboration during periods of heightened tension. The designation of the civilisation became contested: Pakistani archaeologists often preferred Indus Civilisation or Harappan Civilisation, while Indian scholars sometimes emphasised the Sarasvati Civilisation designation to foreground the eastern extension within Indian territory. The discovery of large sites within India — culminating in the identification of Rakhigarhi — partly rebalanced the geographic distribution of known sites, but the partition-imposed institutional division has continued to shape the field in subtle ways, affecting which sites receive sustained excavation funding and how the civilisation's geographic centre is imagined by different national scholarly communities. The post-partition history of IVC research thus illustrates how geopolitical events can restructure archaeological knowledge production in ways that persist long after the immediate political circumstances have changed, and why the development of frameworks for scientific collaboration between Indian and Pakistani archaeological programmes remains an important priority for the field.

Chapter 57

Combined with the French archaeological mission's work at Mehrgarh

(Balochistan, excavated by Jean-François Jarrige and colleagues from 1974), establishing the deep pre-urban Neolithic and Chalcolithic antecedents of Harappan civilisation in the Indus borderlands, Pakistani-based and international collaborative excavation has continued to provide evidence complementary to, and methodologically continuous with, the Indian excavation programme, notwithstanding the political bifurcation of Definition HI.3 and the very different national contexts within which IVC heritage is now interpreted, discussed further in

Chapter 58

The Genomic and Digital Turn: 2000s–2020s

58.1 From Typology to Sequence Data

Definition HI.4: A Methodological Transformation. The period since approximately 2010 has seen IVC studies transformed by the application of two methodological families largely unavailable to the discipline's earlier century: high-throughput ancient-DNA sequencing (the basis of the Narasimhan et al. and Shinde et al. studies reviewed in Part I, made fea- sible by the dramatic cost reductions and sensitivity improvements in next-generation se- quencing technology over the 2010s) and computational corpus analysis applied to the In- dus script corpus (the Rao et al. and subsequent

neural-network studies reviewed in Part IV, made feasible by advances in machine learning and the digitisation of the Indus cor- pus into machine-readable form, principally through the Corpus of Indus Seals and Inscrip- tions project initiated by Mahadevan and continued by subsequent digitisation efforts). Both methodological families have shifted the discipline's centre of gravity away from the typolog- ical and stylistic analysis (seal iconography classification, ceramic seriation) that dominated twentieth-century Indus archaeology and toward quantitative, statistically formalised analy- sis of large datasets — a shift with direct implications for the kind of evidence this study's four analytical engines (Introduction) are each built to evaluate. **Finding HI.4: An Accelerated but More Contested** Public Discourse. The genomic and computational turn has coincided with, and partly driven, a marked acceleration in the public and political salience of IVC research discussed throughout Chapter 24: genomic findings, un- like the typological debates of an earlier era, translate readily into simplified popular claims about ancestry and identity ("the IVC was/was not genetically continuous with population X") that circulate rapidly through digital media in a way nineteenth- and twentieth-century ceramic seriation debates never did, and the same digital infrastructure that has enabled pro- ductive international collaboration (Case Study HI.1) has also enabled the rapid, low-friction circulation of both the rigorous findings and their popular distortions documented in Chap- ter 3. This acceleration is not unique to IVC studies — comparable dynamics affect ancient- DNA research on European, East Asian, and Native American population history — but the IVC case is distinguished by the unusually direct entanglement of its genomic findings with two nations' contemporary politically salient identity narratives simultaneously, a structural feature this volume has treated as definitional from its opening pages.

The application of ancient DNA analysis to South Asian prehistory, brought to transformative scale by Narasimhan et al. (2019), has resolved several long-standing questions while generating new interpretive debates. The confirmation that IVC-related ancestry forms a ma-

jor component of present-day South Asian genomes, combined with the demonstration that Steppe pastoralist ancestry entered South Asia only after the IVC urban phase, has effectively closed the argument for a pre-Harappan or Harappan-era Aryan migration from the perspective of population genetics. Simultaneously, the genomic work has opened questions about the precise demographic relationship between IVC populations and their successor communities. Digital survey methods — including satellite remote sensing, LiDAR, and systematic surface collection with GPS — have transformed the scale at which site distribution can be mapped. Mughal's systematic surveys of the Cholistan desert, which documented hundreds of previously unknown sites, prefigured the more recent remote-sensing work and demonstrated that the IVC's eastern extent had been substantially underestimated. The intersection of these methodological revolutions — ancient genomics and digital landscape archaeology — has created the conditions for a new synthesis of IVC studies that was impossible as recently as 2010, and whose full implications are still being worked out in the ongoing literature. A third development, the expansion of archaeobotanical and stable isotope analysis capacity within South Asian institutions, has begun to produce data on diet, mobility, and agricultural practice that complement the genomic and survey-based findings.

Chapter 59

Independence

The
Discipline's
Institutional
Development
Since

59.1 The Archaeological Survey of India and the Department of Archaeology and

Museums **Definition HIST.1: Post-1947 Institutional Bifurcation. Following the 1947 partition dis- cussed in** Chapter 48, IVC archaeological research was institutionally divided between the Archaeological Survey of India (ASI), which retained continuity with the colonial-era Archae- ological Survey but lost direct access to Mohenjo-daro and Harappa, and Pakistan's newly established Department of Archaeology and Museums, which inherited custodianship of the two largest known IVC cities but a comparatively smaller existing institutional and trained- personnel base. This bifurcation shaped the subsequent research trajectory of each country: Indian archaeology, lacking direct access to the type-sites that had defined the civilisation in the 1920s, was institutionally motivated toward an active programme of new site discovery within Indian territory (ultimately yielding Kalibangan, Lothal, Dholavira, Rakhigarhi, and the broader Gujarat and Rajasthan site corpus), while Pakistani archaeology focused initially on continued excavation and, increasingly from the 1960s onward, conservation of the two major cities already under excavation.

59.2 International Collaborative Projects and the Post-1990s Opening

Finding HIST.1: The HARP Project and Renewed International Access. The Harappa Ar- chaeological Research Project (HARP), a multi-decadal international collaboration beginning in the 1980s under the direction of J. Mark Kenoyer and Pakistani institutional partners, repre- sents a significant post-independence model of sustained international collaborative excava- tion at Harappa itself, producing much of the detailed craft-production, weight-system, and seal-corpus evidence cited

throughout Part VII of this volume. Comparable international col- laborative frameworks have operated at several Indian sites in subsequent decades, and the broad trend across both countries since the 1990s has been toward increased international collaboration and increased

application of archaeometric and genomic methods developed initially in other regional contexts, a trend of which the Narasimhan et al. and Shinde et al. genomic studies discussed in Part I are themselves part, rather than being methodologically isolated events.

The emergence of regional IVC research communities in South Asian universities since the 1990s has begun to diversify not only the institutional base but also the interpretive frameworks within which IVC evidence is analysed. Scholars trained in South Asian institutions bring familiarity with regional languages, oral traditions, and ethnographic knowledge that may illuminate aspects of the archaeological record that are invisible to researchers working exclusively from Western theoretical frameworks. The tension between nationalist interpretive commitments and the requirements of empirical scholarship has been a structural feature of South Asian archaeology since the colonial period, and its resolution requires the development of institutional cultures that reward rigorous critique over politically convenient conclusions — a process that is underway at several South Asian research centres but that faces ongoing pressure from funding bodies and government agencies with stakes in particular historical narratives.

Chapter 60

The Role of Amateur and Avocational Discovery in the

Modern Period

60.1 Site Discovery Outside Formal Survey Programmes

Case Study HIST.1: Rakhigarhi's Discovery Trajectory Rakhigarhi, now recognised as one of the largest known Mature Harappan sites and the source of the genomic sample analysed in Shinde et al. (2019), was first formally reported to archaeological authorities in 1963 but was not subjected to systematic large- scale excavation until several decades later, with the site's true extent only becoming clear through twenty-first-century survey and excavation campaigns — illustrating a recurring pattern in IVC archaeology whereby sites known locally or reported in preliminary sur- veys for years or decades may remain substantially under-excavated until a combination of institutional priority, funding, and (in Rakhigarhi's specific case) the subsequent scien- tific interest generated by its eventual genomic sampling brings sustained large-scale at- tention. This pattern has direct implications for the corpus-expansion scenario discussed in **Definition OQ.3: the slow, uneven, funding-dependent tempo of site excavation histori- cally** observed across the IVC's territory cautions against any confident timeline for when, if ever, additional excavation might substantially expand the inscribed-corpus evidence base relevant to script decipherment.

The contribution of amateur and avocational researchers to IVC studies extends beyond initial site discovery to include the preservation and reporting of finds that might otherwise be lost to the archaeological record. Several significant Harappan objects — including some of the early seals that first attracted professional attention to the civilisation — were recovered and reported by colonial revenue officials, railway engineers, and private collectors who lacked formal archaeological training but possessed the local knowledge and observational capacity to recognise the significance of unusual finds. The development of systematic reporting mechanisms that allow amateur observers to contribute to the archaeological record without exposing sites to uncontrolled excavation or looting represents an ongoing challenge for site management in both India and Pakistan.

Chapter 61

The Naming Problem: ”Indus,” ”Harappan,” and Contested

Terminology

61.1 Why the Civilisation Has No Settled Name

Definition HIST.2: Competing Naming Conventions. The civilisation discussed throughout the present account is variously termed the “Indus Valley Civilisation,” the “Harappan Civilisation” (after its first-identified type-site), the “Indus-Sarasvati Civilisation” (a term favoured by some scholars, particularly those emphasising continuity with the Ghaggar-Hakra system’s identification with the Vedic Sarasvati river, discussed in connection with the Out-of-India hypothesis of Chapter 7), and occasionally the “Sindhu-Saraswati Civilisation” in some Indian popular and political usage. Each naming choice carries, to varying degrees, an implicit interpretive stance: “Harappan” is the most interpretively neutral, naming the civilisation after its type-site without geographic or textual-continuity claims; “Indus Valley” privileges the river system without addressing the substantial Ghaggar-Hakra settlement density documented in Finding GEO.1; and “Indus-Sarasvati” or “Sindhu-Saraswati” explicitly imports the contested Vedic-continuity identification that this volume’s linguistic and genomic chapters (Part II) have shown to rest on a considerably weaker evidentiary basis than such naming would suggest to an uninformed reader. This volume has used “Indus Valley Civilisation” and “IVC” throughout primarily for continuity with the majority of the existing English-language scholarly literature, while flagging here, in closing, that even this

seemingly neutral choice is not entirely free of the naming politics it might appear to avoid.

The political dimension of the naming problem extends to the question of which community’s scholarly tradition has the authority to name the civilisation. The term Indus Valley Civilisation was established by a British colonial official writing in an English-language scientific publication in 1924, and its persistence as the internationally dominant designation reflects the colonial-era power asymmetries that structured the production of knowledge about South Asian prehistory. Post-colonial South Asian scholars have legitimate grounds for preferring alternative designations that reflect indigenous geographic or cultural categories, but the practical requirement of a shared scholarly nomenclature creates pressure toward stability even when the existing convention carries colonial associations. The naming debate thus exemplifies a broader tension in post-colonial archaeology between the intellectual case for decolonising the discipline’s inherited frameworks and the practical requirement of communicating across linguistic and institutional boundaries.

Chapter 62

The Role of Satellite and Remote-Sensing Survey in Recent

Site Discovery

62.1 Extending the Known Site Inventory Without New Excavation

A significant methodological development in IVC archaeology over the past three decades has been the increasing use of satellite imagery, particularly declassified Cold War-era reconnaissance imagery and more recent high-resolution commercial satellite data, to identify candidate site locations across the Ghaggar-Hakra corridor and other parts of the IVC's territorial extent without requiring ground survey as a first step. This approach has substantially expanded the known site inventory, particularly in border regions where ground survey access is logistically or politically constrained, and has contributed directly to the identification of sites such as Ganweriwala's full extent (Chapter 63) and to a broader, still-growing catalogue of smaller, as-yet-unexcavated settlements along the dry palaeo-channel network. This remote-sensing approach, while valuable, carries its own evidentiary limitations di- rectly analogous to those discussed for surface survey more generally in **Note GZ.3: a** site identified from satellite imagery as a probable Harappan-period settlement, on the basis of surface artefact scatter visibility, settlement-mound morphology, or vegetation anomalies indicating buried structures, remains an inference rather than a confirmed identification until ground-truthed by at least preliminary survey, and the much larger number of remote-sensing-identified candidate sites relative to the number that have received even basic ground verification means that the full scale of the IVC's settlement network, while clearly larger than the long-excavated core sites alone would suggest, remains considerably less certain in its precise total extent than the steadily growing site-count figures sometimes cited in popular treatments might imply.

The integration of remote sensing data with community-based archaeological knowledge represents an emerging methodological frontier in IVC studies. Local herders, farmers, and village elders possess detailed knowledge of landscape features — subtle topographic anomalies, unusual soil colour patterns, seasonal changes in vegetation density — that can direct ground survey teams to sites that remote sensing has failed to detect or to features within known sites whose significance is not apparent from satellite imagery alone. Pilot projects combining GPS-equipped community informants with systematic remote sensing survey have demonstrated the potential of this approach in other archaeological contexts, and its application to the under-surveyed areas of the IVC's geographic range — particularly in the frontier zones of Balochistan and the Deccan — represents a methodological opportunity that has not yet been systematically exploited.

Chapter 63

Seal Iconography: The Pashupati Figure, the Unicorn, and

Narrative Scenes

63.1 The Recurring Iconographic Repertoire

Definition RI.1: The Standard Harappan Seal Iconography. The corpus of more than 3,500 catalogued Harappan steatite seals exhibits a remarkably constrained iconographic repertoire: a single animal motif (overwhelmingly the so-called "unicorn," a profile depiction of a bovine- like animal with a single visible horn, present on roughly sixty percent of figurative seals), generally accompanied by a short Indus-script inscription and, frequently, an object resem- bling a ritual stand or offering vessel placed before the animal's head. Other recurring animal motifs — the humped zebu bull, the water buffalo, the elephant, the rhinoceros, and the tiger — each appear with their own distinct frequency and contextual associations, and the con- sistency of this repertoire across the full geographic and (on the chronological evidence of Chapter 9) temporal range of Mature Harappan seal production is itself a further instance of the standardisation pattern documented in the weight and brick evidence of Part VII.

63.2 The Pashupati Seal

Case Study RI.1: Seal M-304 and the Proto-Shiva Hypothesis. A single seal recovered from Mohenjo-daro (catalogued as M-304), depicting a horned, seated figure in a cross-legged posture surrounded by four animals (an elephant, a tiger, a rhinoceros, and a water buffalo, with two additional caprid figures beneath the seat), was interpreted by Marshall in his original 1931 publication as a prototype of the later Hindu deity Shiva in his Pashupati ("Lord of Animals") aspect, on the grounds of the figure's apparent horned headdress, cross-legged yogic posture, and the animal-lordship motif's resonance with later Shaiva iconography. This identification, while still cited in popular accounts and asserted with confidence by some Indigenous Aryanism proponents (Chapter 7) as evidence of direct cultural continuity from the IVC to later Hindu religious tradition, has been treated with considerably more caution in the specialist literature since Marshall's time: the seated posture's identification as specifically "yogic" versus simply seated, the horned headdress's relationship to the later iconographic conventions of Shiva (whose canonical attributes are textually and art-historically attested only more than a thousand years later), and the inferential leap from formal visual resemblance to actual religious continuity across the chronological and, on the evidence of

Part I and Part II, demographic and linguistic discontinuities the IVC underwent, are each inThe Indus Enigma dependently contestable, and the single-seal evidentiary base (M-304's iconographic configu- ration is not closely replicated elsewhere in the corpus) compounds the diiculty of building a strong continuity argument on this evidence alone.

63.3 Narrative and Composite Seals

Finding RI.1: A Small Corpus of Narrative Scenes. A minority of Harappan seals and sealings depict multi-figure narrative scenes rather than the standard single-animal-plus- inscription format: a recurring scene showing a figure grappling with two tigers (paralleled, though not necessarily directly connected, by the Mesopotamian "master of animals" mo- tif and its Gilgamesh-associated iconography); a scene showing a figure in a tree being ap- proached by another figure and a tiger, sometimes read as a worship or sacrifice scene; and composite or "fantastic" animal figures combining anatomical elements of multiple real species. These narrative seals, though too few in number (several dozen examples across the full cat- alogued corpus) to support confident reconstruction of an underlying mythological or ritual narrative, indicate that Harappan visual culture possessed a narrative as well as an emblem- atic register, a capacity whose textual counterpart — if the inscriptions accompanying these scenes name or describe the depicted narrative — remains inaccessible pending the decipher- ment outcome discussed in

The Pashupati seal's ambiguous evidence for proto-Shaiva religion illustrates a more general problem in the interpretation of IVC iconography: the difficulty of distinguishing deliberate symbolic communication from the projection of meaning by interpreters trained in later South Asian religious traditions. The seal's central figure has been read as a prototype of Shiva by generations of scholars, but the reading depends on selecting a subset of the seal's iconographic elements — the seated posture, the horned headdress, the animal companions — and assimilating them to a later iconographic scheme while ignoring elements that do not fit, such as the specific combination of animals depicted and the object before which the figure sits. A more cautious reading acknowledges the seal's extraordinary richness without committing to a specific identification and uses it as evidence for the existence of complex ritual or narrative scenes in IVC visual culture rather than as a window onto IVC theology.

Chapter 64

Ritual Architecture and the Absence of Temples

64.1 The Kalibangan Fire Altars

Definition RI.2: The Kalibangan Ritual Platform Complex. Excavations at Kalibangan (**Ra- jasthan**) by B.B. Lal and B.K. Thapar identified, on a raised platform at the site's citadel mound, a row of seven rectangular pits lined with terracotta cylinders and containing ash deposits and, in several cases, animal bone fragments, interpreted by the excavators as fire altars associated with ritual practice, alongside a separate well and bathing platform in apparent functional association. A further single fire-altar structure was identified within a domestic context in the lower town, suggesting that fire-based ritual, if that is the correct interpretation, was practised at both a communal and a household scale. The Kalibangan fire-altar interpretation has been invoked, with varying degrees of caution, as

a potential material precursor to the fire-altar (agnicayana) tradition documented in later Vedic ritual texts, a continuity claim that, like the Pashupati seal's relationship to later Shaivism (Case Study RI.1), requires the same caution about inferring direct cultural continuity across the chronological and demographic discontinuities established in Part I. **Note RI.1: An Alternative, More Conservative Reading. A** more cautious interpretive line, advanced by some archaeologists sceptical of the fire-altar identification's ritual speci- ficity (the structures' function as ash-disposal or craft-production installations, for instance kiln-related, cannot be entirely excluded on the excavated evidence alone), notes that fire- related installations are common across many functional categories of ancient settlement ar- chaeology, and that the leap from "structure containing ash and showing fire damage" to "ritual fire-altar of a specifically Vedic-precursor type" involves an interpretive step that the physical evidence alone does not compel. This volume notes both readings without adjudi- cating between them, consistent with its general methodological commitment, stated in the Introduction, to flagging rather than resolving disputes that the evidence cannot settle.

64.2 The Persistent Absence of Confirmed Temples

Proposition RI.1: Distributed Domestic Ritual Rather Than Centralised Cult. The absence, noted already in Note MC.1, of any structure at any excavated IVC site that can be confidently identified as a dedicated temple building — in contrast to the unambiguous temple architecture of contemporary Mesopotamia, identifiable by scale, internal cultic furniture, and, frequently, textual dedication — combined with the comparatively widespread distribution of plausible small-scale ritual material (terracotta figurines interpreted as votive or cultic objects, found broadly across domestic contexts rather than concentrated at a single

civic shrine), has led several specialists (Possehl prominent among them) to propose that Harappan religious practice, whatever its specific content, may have been organised around distributed household and small-community ritual rather than around a centralised state cult of the Mesopotamian or Egyptian type — a religious-organisational hypothesis that would cohere with, though it does not independently prove, the heterarchy hypothesis of Definition CC.2.

The apparent absence of dedicated religious architecture in the IVC has been one of the most discussed features of the civilisation, partly because the contrast with Mesopotamia and Egypt — where temples constitute the most extensively documented building type — is so pronounced. The Great Bath at Mohenjo-daro has been interpreted as a ritual bathing facility on the basis of its elaborate waterproofing and central position in the citadel complex, but the identification is inferential: no dedicatory inscriptions, votive deposits, or iconographic programmes confirm a religious function. What is absent is any building combining the formal characteristics of ancient Near Eastern temples: axiality, a progression from profane to sacred space, evidence of animal sacrifice, or votive deposits. The interpretation of this absence varies: some scholars read it as evidence that IVC religious life was decentralised and domestic; others suggest that perishable materials may have been the medium for religious architecture and are therefore invisible; still others argue that the distinction between sacred and secular space was structured differently in the IVC, making the temple concept inapplicable. The question connects directly to the broader debate about political organisation: the absence of a temple-palace complex of Mesopotamian type is consistent with the heterarchical model of IVC governance and with the suggestion that the coordination mechanisms of the IVC operated through commercial and craft networks rather than through religious institutions with centralised property and redistributive functions of the kind that anchored Mesopotamian urban economies.

Chapter 65

Burial Practice and Mortuary Variation

65.1 Cemetery R37 at Harappa

Definition RI.3: The Standard Mature Harappan Burial The most extensively excavated Mature Harappan cemetery, Cemetery R37 at Harappa, documents a recurring burial pattern: extended supine inhumation, oriented with the head generally to the north, accompanied by a modest assemblage of grave goods (pottery vessels, personal ornaments including shell and faience bangles and beads, and occasionally a small number of copper objects) whose quantity and quality vary across in- dividual burials but without the dramatic differentiation in grave-good wealth that would indicate a strongly stratified mortuary hierarchy of the kind documented at, for instance, the Royal Cemetery of Ur. This comparatively modest and comparatively undifferentiated mortuary pattern, replicated with local variation at other excavated Harappan ceme- teries (including a smaller cemetery at Kalibangan and burial evidence from Rakhigarhi, the genomic sampling source discussed in Chapter 2), is a further datum in the broader pattern of archaeologically muted elite display discussed throughout

The mortuary evidence from the IVC raises important questions about the relationship between burial practice and social organisation that the existing data cannot fully resolve. The relatively modest differential in grave wealth observed at IVC cemeteries, compared to the sharp gradients visible in contemporaneous Mesopotamian royal burials or in the kurgan burials of the Eurasian steppes, is consistent with the heterarchical model of IVC political organisation but does not prove it: mortuary practice is only one of many dimensions on which social stratification is expressed, and the IVC's social hierarchy may have been expressed primarily through access to craft goods, residential space, and exchange networks rather than through funerary display. The systematic comparison of residential architecture and domestic assemblages across different areas of the same IVC urban site — a form of analysis that has been applied at Harappa by the Harappa Archaeological Research Project — offers a complementary approach to the question of social differentiation that is less dependent on the fragmentary mortuary record.

Chapter 66

Case Study RI.2: Multiple Burial Traditions at a Single Site. Recent reanalysis of Harappa's mortuary

evidence (Schug et al., applying isotopic and osteological analysis alongside the genomic work discussed in Chapter 2) has identified evidence for more than one concurrent burial tradition at the site, including fractional or secondary burial practices alongside the standard extended inhumation of Definition RI.3, and isotopic evidence consistent with at least some individuals having immigrated to Harappa from elsewhere within or beyond the IVC's territory during their lifetime — direct skeletal evidence of the population mobility that the genome-wide ancestry cline evidence of Chapter 1 establishes at a broader demographic scale, now visible at the level of individual life histories.

66.1 Regional and Chronological Variation: Cemetery H

Finding RI.2: A Mortuary Discontinuity at the Urban-to-Post-Urban Transition. Cemetery H at Harappa, stratigraphically and materially distinct from Cemetery R37 and dated to the Late Harappan / post-urban period following the IVC's mature-phase decline (the chronological transition discussed in Chapter 11), documents a markedly different burial tradition including fractional and urn burial practices, a distinct and stylistically novel painted-pottery tradition (the Cemetery H pottery style, decorated with motifs including birds and what have been interpreted, speculatively, as mythological scenes), and burial in stratigraphic contexts directly overlying the ruins of Mature Harappan structures. The Cemetery H discontinuity has historically been invoked, in older diffusionist literature, as evidence for the arrival of a new population displacing or succeeding the Mature Harappan population, an interpretation that the genomic evidence of Part I now allows to be evaluated more rigorously than was possible when the cemetery was first excavated: the chronological window of the Cemetery H transition is broadly compatible with, though not so precisely dated as to confirm in detail, the early phase of the Steppe-ancestry admixture process documented in Chapter 1, making Cemetery H a candidate archaeological correlate for the broader demographic transition this volume's genomic engine documents at the population-genetic scale, albeit one requiring further direct chronometric and, ideally, genomic work on the Cemetery H skeletal sample itself before the correlation can be considered established rather than merely consistent.

Chapter 67

The Proto-Shiva Seal and the Limits of Iconographic

Continuity Arguments

67.1 Marshall's Identification and Its Subsequent Critique

Definition REL.1: The Pashupati Seal. One of the most frequently reproduced objects in the IVC iconographic corpus is a Mohenjo-daro seal (M-304) depicting a horned, seated figure surrounded by animals, which John Marshall, in his original 1928–1931 excavation report, identified as a "proto-Shiva" or "proto-Pashupati" (Lord of Animals) figure, drawing an explicit continuity line to the later Hindu deity Shiva in his aspect as Pashupati. This identification, made on the basis of broad iconographic resemblance (the seated, horned, animal-surrounded posture) rather than any textual or linguistic evidence, has been enormously influential in popular and some scholarly discussion of IVC religion in the subsequent cen- tury.
Finding REL.1: Why the Proto-Shiva Identification Is Now Widely Qualified. Subse- quent iconographic scholarship (Srinivasan 1975, 1997; Possehl 2002) has substantially qual- ified Marshall's original identification, noting that: (a) the seated yogic posture Marshall emphasised is one of several possible readings of an ambiguous carved pose; (b) the specific horned headdress shown does not closely match later canonical Shiva iconography, which develops its

own distinctive visual conventions over the subsequent two millennia largely in- dependently of any demonstrable Indus antecedent; (c) similar seated-figure-with-animals motifs occur, with significant variation, across other ancient Near Eastern and Central Asian iconographic traditions without any of those traditions being linked to later Hindu deity de- velopment, suggesting that the broad motif type (a seated authority figure flanked by or master of animals) may be a recurring cross-cultural iconographic convention rather than a marker of specific religious-historical continuity. Most current specialist treatments ac- cordingly present the "proto-Shiva" label as a historically important but evidentially weak interpretive hypothesis from the formative period of Indus archaeology, rather than as an established finding, a Tier 2 caution directly analogous to those developed for the linguistic continuity claims of Part II.

67.2 Fire Altars and the Vedic Continuity Debate

Case Study REL.1: The Kalibangan "Fire Altars". Excavations at Kalibangan identified a row of brick-lined pit features interpreted by the original excavators (B.B. Lal) as ritual fire

altars structurally comparable to later Vedic agnihotra fire-altar practice, an identification that has been cited in support of arguments for direct cultural continuity between the IVC and later Vedic religious practice. Critics (Shaffer & Lichtenstein 1995) have countered that the Kalibangan pits' function is also consistent with mundane domestic or craft-production uses (kilns, hearths, or refuse pits) without invoking any specifically ritual interpretation at all, and that the identification with later Vedic fire-altar practice specifically, as opposed to a generic and cross-culturally common use of fire pits, requires an inferential leap the structural evidence alone does not support. The fire-altar case is a clear instance of the general iconographic-and-architectural-continuity evidentiary weakness pattern documented throughout this chapter and

The Proto-Shiva seal from Mohenjo-daro, depicting a horned anthropomorphic figure surrounded by animals including rhinoceros, buffalo, elephant, and tigers, has generated an interpretive literature disproportionate to its uniqueness. Marshall's identification of the figure as a prototype of the historical Shiva Pashupati established an interpretive frame that has proven remarkably persistent despite sustained criticism. The problems with the identification are multiple: the figure's posture cannot be confirmed as intentionally representing the yogic meditator; the horned headdress has parallels in non-South Asian Bronze Age iconography; and the attribution of a specifically Shaiva identity imports a historical religious category into a context where that category may not have existed. Srinivasan (1975–76) argued that the horns are in fact a buffalo-horn motif common in the broader Bronze Age visual vocabulary. More recently, scholars have emphasised the composite and ambiguous nature of the scene as evidence of its resistance to monocausal iconographic reading. The seal's significance as evidence for continuity between IVC religion and historical Hinduism — frequently asserted in popular and nationalist literature — is not supported by the specialist consensus, which treats the identification as speculative. More cautious interpretive frames acknowledge that the scene likely had specific meaning for its makers coherent within their cultural context, while accepting that this meaning is currently unrecoverable and that projecting later South Asian religious categories onto it is methodologically unsound.

Chapter 68

Burial Orientation and Funerary Variation Across Sites

68.1 A Patterned but Not Fully Uniform Practice

Harappan burial practice, documented most fully at the Harappa cemetery (Cemetery R-37) and at smaller cemetery samples from other sites, shows a generally consistent pattern of extended supine burial with the head oriented toward the north, accompanied by a modest range of grave goods (pottery vessels, occasional personal ornaments, and in some burials small quantities of food offerings inferred from associated animal bone), but with enough site-to-site and even within-site variation in specific orientation and grave-good composition that scholars have generally been cautious about inferring a single rigid pan-Harappan funerary doctrine from the burial evidence. This combination of a clear central tendency with meaningful variation around it is consistent with the broader pattern, observed across the brick, weight, and ceramic standardisation evidence of Part VII, of a civilisation organised around strong shared conventions that nonetheless tolerated, and perhaps did not strongly enforce uniformity in, the more personal and locally determined domains of practice that funerary custom plausibly represents.

The regional variation in IVC burial practice raises the possibility that different communities within the IVC participated in distinct funerary traditions that reflected different social or religious affiliations rather than a single uniform practice across the civilisation. The contrast between the extended inhumation predominating at Cemetery R-37 at Harappa and the fractional burial evidence at Cemetery H at the same site, interpreted as evidence of a temporal transition, may alternatively reflect the coexistence of different communities with different mortuary norms within the same urban centre. Similar diversity has been documented at Lothal, where a small number of double burials — two individuals interred together — has prompted speculation about paired burial practices analogous to those known from other Bronze Age cultures, though the evidence is too limited to support strong conclusions.

Chapter 69

Harappa: The Type Site

69.1 A Site Defined by Its Damage

Definition GZ.1: The Railway-Ballast Problem. Harappa occupies an unusual position among the IVC's major urban centres: it is the type site that gave the civilisation its conventional name (Sahni's 1920 excavations, Definition HI.1), yet it is also the most severely damaged of the major mounds, having been used through the nineteenth century as a source of fired brick for railway ballast during the construction of the Lahore-Multan line, a practice that removed an unknown but almost certainly substantial fraction of the site's uppermost structures before any archaeological recording took place. This damage means that inferences about Harappa's original monumental layout — and in particular the comparative state of its citadel mound relative to the better-preserved citadel at Mohenjo-daro — must be treated with additional caution, since the absence of a feature at Harappa is harder to interpret as a genuine absence rather than as brick-robbing loss than the equivalent absence at a less disturbed site.

69.2 The Granary Reinterpretation

Finding GZ.1: From State Granary to Uncertain Function. A large platform structure on Harappa's citadel mound, originally identified by Wheeler as a state granary on the model of comparable structures he had previously excavated in Britain and at Mohenjo-daro (where an analogous structure received the same interpretation), has been substantially reassessed in subsequent scholarship: no charred grain or other direct botanical evidence of cereal storage has been recovered from either the Harappa or the Mohenjo-daro "granary," and the structures' air-circulation and loading-access features, on which Wheeler's functional inference partly rested, are now considered less diagnostic than originally claimed. Kenoyer and other specialists working at Harappa since the 1980s have proposed alternative functions (a platform for craft production, a public or ceremonial structure) without reaching consensus, and the "granary" label, while still used informally, is now generally flagged in the specialist literature as an inherited interpretation requiring the same caution this volume applies throughout to functional claims about Harappan architecture that outrun the available physical evidence.

69.3 Craft Quarters and Urban Zonation

Case Study GZ.1: Workshop Concentration as Evidence of Zonal Specialisation. Exca- vation of Harappa's residential mounds (designated Mound E and Mound ET in the site's

excavation nomenclature) has identified concentrations of craft-production debris — bead-manufacture waste, shell-working debitage, and ceramic kiln remains — suiciently localised to indicate that specific quarters of the lower town were given over substantially to particular craft activities, a pattern of functional zonation that, combined with the standardised street grid of Finding MC.1, suggests a level of urban planning extending beyond the citadel-lower town division into the internal organisation of the residential city itself, though the mechanism (deliberate allocation versus organic clustering of craft lineages) cannot be determined from the spatial evidence alone.

Harappa's designation as the type site reflects the accident of discovery as much as its intrinsic significance. The site had sustained severe damage from brick robbing — the same fired Harappan bricks that had served as ballast for the Lahore-Multan railway had removed substantial portions of the archaeological sequence before systematic investigation began. Cunningham's 1870s visit had recognised the antiquity of the site but failed to identify it as belonging to a distinct urban civilisation. The Harappa Archaeological Research Project, initiated by Kenoyer and Meadow in 1986, has transformed understanding of the site through modern stratigraphic methods, systematic flotation, and a chronological framework extending from the pre-Urban Ravi Phase (circa 3500 BCE) through the Harappan Phase and into the Late Harappan transition. The Ravi Phase assemblages, predating the emergence of characteristic Indus script and standardised weights, provide evidence for the developmental trajectory out of which the Mature Harappan urban culture emerged. Harappa's position on the Ravi tributary rather than the main Indus channel may have given it specific advantages related to access to highland resources via the Beas corridor. The site's ongoing investigation represents the longest continuously running modern excavation programme at any IVC site and has been central to the methodological renewal of South Asian Bronze Age archaeology over the past four decades, serving as a training ground for a generation of Pakistani, Indian, and international archaeologists whose work has collectively transformed the field.

Chapter 70

Lothal and the Gujarat Periphery

70.1 A Coastal Node at the IVC's Southern Margin

Definition GZ.2: Lothal's Position in the Settlement Hierarchy Lothal, situated near the head of the Gulf of Khambhat in Gujarat, occupies a po- sition at the southern margin of the IVC's core distribution, smaller in overall extent than Mohenjo-daro or Harappa but possessing a citadel-lower town layout, standardised weights and bricks conforming to the Definitions of Chapter 28 and 30, and the contested basin structure of Proposition MC.4. Its location gives it direct access to the bead-working, shell-working, and copper-supply networks of the Gujarat and Saurashtra region (Chap- ter 29) and to maritime routes toward the Gulf and, ultimately, the Meluhha-DilmunMesopotamia exchange system of Chapter 31, a combination that has led most specialists to characterise Lothal as a specialised craft-production and trade-node settlement within the IVC's broader regional system rather than as a centre of comparable political weight to the Indus-trunk cities.

70.2 Material Evidence for Direct Exchange

Proposition GZ.1: Lothal's Persian Gulf Seal as a Direct Trade Indicator. A circular "Persian Gulf"-style steatite seal of the type described in Finding MC.4, along with other artefact classes (a terracotta ship model with a stepped mast socket, weights conforming to the standard series) recovered at Lothal, provides among the most direct site-level evidence available for an individual IVC settlement's participation in the long-distance Gulf exchange network documented at the aggregate, civilisation-wide level in

The rich assemblage recovered from Lothal, including a large collection of carnelian and faience beads, numerous terracotta figurines, and evidence for specialised craft production in multiple materials, confirms the site's role as a significant centre of production and exchange within the southern IVC network. The fire altar complex at Lothal, similar to the platforms identified at Kalibangan, has been interpreted as evidence for ritual activity of a kind that may have had an organisational function — coordinating the activities of the craft and commercial community through shared ceremonial practice — in addition to or instead of a purely religious function. The site's archaeobotanical record, dominated by rice and millet in the later phases, reflects the ecological conditions of the Gujarat coast and documents the integration of rice cultivation into the IVC subsistence system at an earlier date than has been confirmed at Indus heartland sites.

Chapter 71

This does not by itself re- solve the basin’s specific

dockyard-versus-reservoir function (Proposition MC.4), but it does establish that whatever the basin’s function, the settlement as a whole was materially engaged with the Gulf exchange circuit in a manner that a purely inland agricultural site would not exhibit.

Chapter 72

Kalibangan and Surkotada: Two Regional Variants

72.1 Kalibangan: The Ghaggar-Hakra Heartland

Definition GZ.3: Kalibangan's Pre-Harappan and Harappan Sequence. Kalibangan, on the now-dry Ghaggar-Hakra palaeo-channel in Rajasthan, exhibits an unusually well-documented stratigraphic transition from an Early Harappan (pre-urban, regionally distinctive ceramic and architectural) occupation phase into the Mature Harappan urban phase, including, in the Early Harappan levels, a ploughed agricultural field surface preserving a furrow pattern interpreted as evidence of a specific ridge-and-furrow cultivation technique still practised in the region, providing rare direct evidence (rather than the indirect archaeobotanical evidence of Chapter 21) for Harappan-period agricultural technique. The site's fire-altar evidence (Definition RI.2) and its location within the eastern Ghaggar-Hakra settlement-density zone of Finding GEO.1 make it a key reference point for the eastern, monsoon-dependent portion of the IVC's territory, a portion disproportionately affected by the 4.2 ka aridification event discussed in

The Kalibangan fire altar complex, if the identification is accepted, would represent the earliest material evidence for fire ritual in South Asia and would have significant implications for the long-standing debate about the relationship between IVC religious practice and the fire sacrifice (yajna) that is central to the Vedic ritual system. However, the identification requires accepting that the mud-brick platforms with associated ash deposits served a ritual rather than a domestic or industrial function — an inference that is plausible but not demonstrated by the evidence alone. The comparison with Vedic fire altars is rendered problematic by the chronological gap between the IVC platforms and the earliest Vedic texts, and by the absence of any independent evidence connecting the two traditions. The fire altar interpretation thus exemplifies the broader challenge of identifying religious function in the absence of texts or explicit iconographic programmes, a challenge that is pervasive in IVC archaeology.

Chapter 73

61.2 Surkotada: A Small Fortified Outpost

Case Study GZ.2: Surkotada's Compact Fortified Plan. Surkotada, a comparatively small (approximately 1.4 hectare) fortified site in Kutch (Gujarat), excavated by J.P. Joshi from 1971, combines a citadel and residential area within a single contiguous fortification wall rather than the separated citadel-lower town mounds of the larger urban centres, a compact plan that some specialists read as evidence of a defensive or frontier-outpost function dis- tinct from the larger cities' primarily civic fortification function discussed in Definition CC.4. Surkotada is best known outside specialist circles for the contested equid remains addressed in Note MC.2, and its small scale relative to

Mohenjo-daro and Harappa exemplifies the IVC settlement hierarchy's wide range, from the largest urban centres down to small fortified or specialised outposts whose specific role within the broader settlement system remains, in many cases, inferred rather than directly documented.

Chapter 74

Late Harappan Diversification: Cemetery H, Jhukar, and

Regional Successor Cultures

74.1 The Post-Urban Fragmentation

Definition GZ.4: Regional Successor Traditions. Following the urban decline discussed in Chapter 11, the IVC's formerly integrated material-culture zone fragmented into a series of regionally distinct successor traditions, each retaining some elements of Harappan material culture while developing locally distinctive features: the Cemetery H culture in the Punjab (Definition RI.3's mortuary discontinuity, associated with a distinctive painted pottery style); the Jhukar culture in Sindh, characterised by a ceramic assemblage showing some continuity with Mature Harappan forms alongside new elements whose origin (local innovation versus external contact) remains debated; and the Late Harappan or Sorath Harappan continuation in Gujarat and Saurashtra, where settlement continued with a gradually transforming material culture into the early second millennium BCE, later than the urban collapse in the Indus and Ghaggar-Hakra heartland proper. **Finding GZ.2: Regional** Diversification as Evidence Against a Single Catastrophic End. The geographic patterning of Late Harappan successor cultures — distinct regional traditions persisting on different chronological trajectories in different parts of the former IVC territory, rather than a single synchronous collapse followed by uniform abandonment — is among the strongest archaeological arguments against the simplistic single-cause, single-event collapse narrative criticised in Chapter 10, and instead supports the multi-causal, regionally differ- entiated decline process this study's archaeological engine treats as the best-supported re- construction: urban florescence ending earliest and most abruptly in the climate-vulnerable Ghaggar-Hakra zone (consistent with the monsoon-failure mechanism of Chapter 10), while the Indus-trunk and Gujarat zones, with their differently structured water resources (Chapter 20), show a more gradual and geographically staggered transformation rather than abandon- ment.

The regional diversification of the Late Harappan period represents not only a cultural transformation but a demographic reorganisation whose geographic expression is only beginning to be understood through the combination of settlement survey, archaeobotanical evidence, and ancient DNA data. The eastward dispersal of populations into the Gangetic plain, documented in the spread of Late Harappan ceramic traditions and in the appearance of rice agriculture in the eastern piedmont zone, suggests a large-scale movement of people that would have brought IVC-related cultural and genetic heritage into contact with the populations of the eastern subcontinent for the first time. The demographic consequences of this interaction — the mixing of IVC-descended populations with the Ancient Ancestral South

Indian populations of the eastern and southern subcontinent — may be visible in the present-day genomic structure of South Asian populations, though the ancient DNA evidence needed to document it directly is not yet available.

Chapter 75

Ganweriwala and the Unexcavated Fifth City

75.1 A Major Site Known Almost Entirely from Survey

Definition GZ.3: Ganweriwala's Surface-Survey Profile Ganweriwala, located in the Cholistan desert of Pakistani Punjab along the dry Ghaggar-Hakra palaeo-channel, is estimated from surface survey and remote sensing to rival Mohenjo-daro and Harappa in areal extent, making it one of the largest known Ma- ture Harappan urban centres, yet it remains, as of this volume's composition, essentially unexcavated below the surface level, with current knowledge derived almost entirely from surface artefact collection and satellite-imagery-assisted survey mapping (Mughal 1997) rather than from stratigraphic excavation. This makes Ganweriwala a particularly clear illustration of the corpus-expansion potential, and its current limits, discussed in **Definition OQ.3: a site of this scale, if and when excavated, could** substantially expand the inscribed-seal corpus and the site-plan evidence base, but no excavation programme has yet been funded or scheduled, and the site accordingly functions, for now, as a reminder that the IVC's known archaeological record is bounded as much by excavation funding and access history as by the ancient civilisation's actual territorial extent.

Note GZ.3: The General Lesson of the Unexcavated Major Site. Ganweriwala is not unique: a meaningful fraction of known, surface-surveyed Mature Harappan sites across the Cholistan and broader Ghaggar-Hakra corridor remain similarly unexcavated or only minimally test-trenched, for reasons of funding priority, site access (some sites lie in militarily sensitive border zones), and the sheer number of known sites relative to available excavation resources. This volume's repeated caution against treating the currently excavated evidence base as necessarily representative of the IVC's full archaeological reality (echoed in the organic-preservation caution of Proposition WHL.1 and the script-corpus-size caution of Definition OQ.3) applies with particular force to the unexcavated major-site category that Ganweriwala exemplifies.

The significance of Ganweriwala as an unexcavated site extends beyond its potential contribution to the comparative study of IVC urbanism to the broader question of how the civilisation's political geography was organised. If Ganweriwala was indeed a major urban centre comparable in scale to Mohenjo-daro and Harappa, its position on the Hakra palaeochannel — equidistant in some sense between the two excavated major cities — has been interpreted as suggesting a pattern of urban spacing that may reflect the organisation of hinterland territories or exchange networks. Models of IVC political geography based on Thiessen polygons or other spatial analytical approaches have proposed that the major urban centres were the nodes of distinct territorial or exchange units, a hypothesis that Ganweriwala's excavation would directly test.

Chapter 76

Sutkagan Dor and the Westernmost Extent of the IVC

76.1 The Makran Coastal Frontier

Case Study GZ.1: Sutkagan Dor as a Boundary Marker. Sutkagan Dor, located near the modern Iran-Pakistan border on the Makran coast, is generally regarded as the westernmost confirmed Mature Harappan settlement, featuring a stone-built citadel wall constructed in a style showing some local adaptation (the use of stone rather than the fired brick standard of Definition T.1, reflecting local material availability) alongside otherwise recognisably Harappan ceramic and seal material. Its extreme western location, combined with the Shortughaï site's extreme northern location (Proposition GEO.1) and the Daimabad site's southern Deccan location, brackets the IVC's documented direct settlement extent at a territorial scale exceeding 1.5 million square kilometres, though the lower-intensity, more sparsely distributed nature of settlement at these peripheral extremes, relative to the dense core zones documented in Finding GEO.1, indicates a civilisation with a strong, densely settled core and a more attenuated, lower-intensity periphery rather than uniform settlement density across its full nominal territorial extent.

The Makran coastal sites, of which Sutkagan Dor is the best documented, suggest that the IVC's maritime frontier was not a passive edge of the civilisation's distribution but an active zone of commercial and possibly political engagement with the communities of the Persian Gulf and the Arabian Sea littoral. The Oman Peninsula sites, particularly Ras al-Junayz, have yielded Harappan pottery, carnelian beads, and other IVC-type objects in contexts suggesting a regular commercial relationship rather than occasional contact. The identification of a small number of possible IVC-related structures at Gulf sites has prompted discussion of whether IVC merchants established permanent trading stations in the Gulf, analogous to the Shortughai outpost in Central Asia, though the evidence for this is less compelling than for the Central Asian case.

Chapter 77

Daimabad and the Southern Deccan Frontier

77.1 The Southernmost Major Settlement

Case Study GZ.2: Daimabad's Bronze Hoard. Daimabad, on the Pravara River in Maharashtra's Deccan plateau, represents the IVC's southernmost major excavated settlement and is best known for a remarkable hoard of large solid-cast bronze sculptures — a chariot drawn by bovines, an elephant, a rhinoceros, and a buffalo, each roughly life-sized in miniature and considerably larger and more technically ambitious than the small bronze figurines known from the Indus core sites. The hoard's stratigraphic and chronological placement, at the transition between the Late Harappan and subsequent local Deccan Chalcolithic cultural phases, has generated debate over whether it represents a continuation of Harappan large-scale casting capability into a peripheral late phase, or a distinct local Deccan bronze-casting tradition only loosely connected to the core Harappan metallurgical tradition discussed in Chapter 80, illustrating once more the interpretive diiculty of assigning peripheral material culture un- ambiguously to a single civilisational tradition, a diiculty already raised for Ganeshwar-Jodhpura in Case Study MET.1.

The Daimabad bronzes, whatever their precise cultural affiliation, represent the high point of IVC-related bronze technology in its spatial dimension. The lost-wax casting technique used to produce the chariot and animals at Daimabad is technically equivalent to the finest contemporary Mesopotamian bronzework, and the scale of the objects — the chariot model is approximately 34 centimetres long and weighs several kilograms — required both substantial copper supply and a high level of metallurgical skill. The copper source for the Daimabad bronzes has not been definitively identified, but the Deccan region hosts copper deposits that could have supported local metallurgy, and the existence of a Late Harappan-affiliated metallurgical tradition in the southern Deccan is consistent with the broader pattern of IVC technological diffusion into marginal and frontier zones during the decline phase.

Chapter 78

Shortughaï Revisited: The Northern Trade Colony in

Comparative Light

78.1 A Deliberate Colony Rather Than an Indigenous Settlement

Note GZ.4: Shortughaï's Distinct Settlement Logic Shortughaï, in northern Afghanistan, differs from every other site discussed in this gazetteer in that it is best interpreted not as an indigenous Harappan-zone settlement but as a deliberately established trading colony, positioned to access the lapis lazuli sources of Badakhshan and other Central Asian resources feeding into the long-distance exchange networks discussed in Chapter 83 and

The Shortughai evidence for IVC presence in Central Asia provides an important data point for evaluating models of the relationship between the IVC and the BMAC. The proximity of Shortughai to BMAC settlement zones in northern Afghanistan implies that Harappan merchants operating in the Kokcha valley would have been in regular contact with BMAC communities, and the material record at Shortughai shows traces of BMAC influence alongside the dominant Harappan assemblage. This contact zone, situated at the intersection of three major Bronze Age cultural spheres (IVC, BMAC, and the Inner Asian Steppe zone to the north), was well positioned to serve as a node of cultural and genetic exchange — a role that the genomic evidence for BMAC-ancestry admixture in the earliest Steppe-admixed South Asian individuals may be beginning to document.

Chapter 79

Its full Harappan material-culture profile (standard ceramics, weights, and seals, per Mughal 1972) at

such geographic re- move from the Indus core zone, combined with the absence of any plausible large indige- nous population at the site prior to Harappan-ailiated settlement, supports the colony interpretation over alternative explanations involving large-scale indigenous adoption of Harappan material culture, and stands as the clearest single piece of evidence that the IVC engaged not merely in passive long-distance exchange but in active, organised resource-acquisition expansion at its furthest documented periphery.

The absence of cuneiform-style administrative records from the IVC is a fundamental asymmetry in the comparative evidence that cannot be wished away by invoking the possibility of perishable media. Even if IVC administrators recorded transactions on palm leaves or wooden tablets, the near-total absence of clay impression evidence for extensive accounting — of the kind that Mesopotamian accountants routinely created as a byproduct of administrative practice — is itself informative. It suggests either that the scale and intensity of administrative recording was substantially lower in the IVC than in Mesopotamia, or that the IVC employed administrative technologies so different from the clay tablet tradition that they leave no comparable archaeological signature. The former possibility is consistent with a more decentralised exchange system; the latter remains speculative without positive evidence.

Chapter 80

Surkotada and the Horse Bone Controversy

80.1 A Single Site at the Centre of a Disproportionately Large Debate

Surkotada, a small fortified Mature Harappan site in Kutch, Gujarat, excavated by J.P. Joshi, has occupied an outsized place in the broader Indo-Aryan migration debate because of a reported equid bone assemblage that the excavation's faunal analyst, A.K. Sharma (1974), identified as true domestic horse (Equus caballus) remains, an identification subsequently examined and endorsed by the specialist archaeozoologist Sándor Bökönyi (1997). If correct, the identification would be significant because true domestic horse is otherwise essentially absent from the secure Mature Harappan faunal record and is more closely associated with the later steppe-derived populations discussed in the genomic chapters of Part I. Subsequent specialist re-examination (Meadow & Patel 1997) has challenged the identification, arguing that the morphological criteria used to distinguish horse from other equids present in the South Asian Bronze Age faunal record, including onager and half-ass species, are not as reliably diagnostic as Sharma and Bökönyi's identification assumed, and that the Surkotada material is more cautiously read as ambiguous equid remains rather than confirmed horse. This relatively narrow zooarchaeological dispute has taken on outsized political signifi- cance because it intersects directly with the Out-of-India hypothesis debate of Chapter 7: con- firmed Mature Harappan domestic horse would be cited as evidence against a later steppe- associated horse introduction, while the more cautious re-identification removes this particu- lar piece of evidence from the debate without thereby resolving the broader migration ques- tion one way or the other. The Surkotada case is included in this gazetteer specifically as an illustration of how a single, specialist, and on its own terms relatively modest zooarchaeolog- ical identification question can become disproportionately weighted in public debate once it is recognised as bearing on a larger contested narrative, a dynamic this volume's Part on reception and public discourse (Part XVI) discusses in more general terms.

The broader implications of the Surkotada controversy for archaeological methodology extend beyond the specific question of horse identification to the general problem of how politically contentious scientific questions should be handled when the evidence is genuinely ambiguous. The standard of evidence required to establish a positive claim — in this case, the presence of domestic horse in Late Harappan context — should in principle be the same regardless of the political implications of the claim. In practice, the political stakes attached to the horse question in the context of the Aryan migration debate have led scholars on both sides to apply asymmetric standards of evidence, accepting or rejecting the identification on the basis of prior commitments rather than on the basis of the osteological evidence alone. An-

cient DNA analysis of the Surkotada equid material, if conducted and published following accepted protocols, would remove the ambiguity by providing a definitive species identification independent of morphological judgment.

Chapter 81

The Y-Chromosome Haplogroup R1a Debate

81.1 A Single-Locus Proxy With a Long and Contested History

Definition EG.1: R1a and the Steppe-Migration Question. The Y-chromosome haplogroup R1a, and in particular its R1a1a1b2 (Z93) subclade, occurs at notably elevated frequency among many present-day Indo-European-speaking populations of South Asia, particularly among upper-caste groups in northern India, a pattern that pre-genome-wide-sequencing researchers (working with single-locus Y-chromosome and mitochondrial markers through the 1990s and 2000s) debated intensely as either evidence for a Steppe-derived migration into South Asia or, in competing readings, evidence for an indigenous South Asian origin of R1a with secondary expansion outward toward the Steppe and Europe. This single-locus debate, conducted before genome-wide ancient DNA became available, was unable to resolve the directionality question with confidence, since Y-chromosome frequency data from modern populations alone cannot distinguish a South-Asian-origin-with-outward-expansion scenario from a Steppe-origin-with-inward-migration scenario without an ancient-DNA time series of the kind Part I of this volume reviews. **Finding EG.1: Ancient DNA Resolves the Directionality** Question. The genome-wide ancient-DNA evidence reviewed in Chapter 1, combined with direct ancient Y-chromosome sequencing from Steppe, Central Asian, and South Asian skeletal samples, has resolved the directionality question that single-locus modern-population data could not: R1a-Z93 is docu- mented in ancient genomes from the Central Asian Steppe-pastoralist-associated populations (the Sintashta and related cultures) that, on the genome-wide autosomal evidence, are the source of the Steppe ancestry component entering South Asia in the chronological window discussed in Chapter 1, and is absent or vanishingly rare in pre-Steppe-admixture ancient South Asian genomes including the Rakhigarhi individual of

The Y-chromosome haplogroup R1a became a focal point of the Out-of-India debate because its South Asian distribution was used to argue for a South Asian origin followed by westward migration. High-resolution phylogenetic analysis of R1a has substantially clarified the picture: the South Asian subclade (R1a-Z93) and the European/Steppe subclade (R1a-Z283) diverged from a common ancestral lineage estimated at approximately 5,800 years ago. The internal branching structure of Z93 in South Asia is consistent with relatively recent introduction within the last 4,000 years rather than deep local diversification. Underhill et al. (2015) and Poznik et al. (2016) independently confirmed the chronological and geographic structure of R1a phylogeography in ways broadly inconsistent with the OIT scenario. The autosomal genomic evidence from Narasimhan et al. (2019) independently corroborates the westward-to-eastward directionality of the migration. A persistent OIT response has ques-

tioned the reliability of mutation rate calibrations used to date the R1a divergence, arguing that if mutation rates are slower than assumed, the divergence time would be older and more consistent with a South Asian origin. While calibration uncertainty is a genuine issue in molecular dating, the range of plausible calibration values does not produce estimates old enough to support the OIT scenario without invoking additional assumptions about population structure that are themselves unsupported by the broader genomic evidence from ancient and modern South Asian individuals.

Chapter 82

This ancient-DNA time series establishes a Steppe-to-South-Asia

direction for the specific R1a-Z93 lineage with a degree of chronological resolution that the modern-population frequency data debated in the pre-2015 literature could never achieve, definitively superseding the older single-locus controversy without itself resolving the higher-tier linguistic and identity questions of Chap- ters 6 through 8, which remain governed by the tier-distinction framework of Definition 0.1.

82.1 Why a Y-Chromosome Finding Cannot Settle a Population-History Question

Alone **Note EG.1: The Single-Locus Fallacy. A persistent error in both popular and some academic** treatments of the R1a evidence is to treat a single Y-chromosome lineage's history as equiv- alent to the population history of an entire group: Y-chromosome lineages, being inherited along a single paternal line, can have a different demographic history from the genome-wide autosomal ancestry of the same population, particularly under social systems (such as patri- lineal, patrilocal marriage with differential male reproductive success, documented in various forms across South Asian history) that can amplify or dampen the frequency of specific pa- ternal lineages independent of overall autosomal admixture proportions. The genome-wide qpAdm modelling reviewed in Definition A.2, which integrates information across hundreds of thousands of autosomal loci rather than a single non-recombining lineage, is for this reason the more reliable source of the admixture-proportion estimates this study relies upon, with the Y-chromosome evidence serving a corroborating rather than a primary evidentiary role.

Chapter 83

Mitochondrial DNA and Maternal Lineage Continuity

83.1 A Contrasting Pattern on the Maternal Line

Definition EG.2: Predominantly Local Maternal Ancestry. Mitochondrial DNA studies of modern South Asian populations, predating and subsequently corroborated by ancient mitochondrial sequencing, have consistently found that the great majority of South Asian maternal lineages belong to haplogroups (principally M and its numerous regional subclades, alongside U2 and other deep South-Asian-associated branches) with very deep regional time-depth, generally tens of thousands of years, and showing comparatively little signal of recent Steppe-associated maternal lineage input relative to the Steppe-associated Y-chromosome signal of Definition EG.1. **Finding EG.2: A** Sex-Biased Admixture Signature. The asymmetry between the com- paratively strong Steppe-associated paternal (Y-chromosome) signal and the comparatively weak Steppe-associated maternal (mitochondrial) signal is read by population geneticists (Silva et al., and subsequent work building on the genome-wide framework of Narasimhan et al.) as evidence for a sex-biased admixture process accompanying the Steppe migration into South Asia, in which incoming Steppe-associated males contributed disproportionately to the gene pool relative to incoming Steppe-associated females, a pattern that recurs, with vary- ing intensity, in several other documented instances of Steppe-pastoralist expansion across Bronze Age Eurasia (including, on the genomic evidence reviewed in comparative population- genetic literature, parts of the Corded Ware-associated expansion into Europe). This sex- biased pattern is a genuine and well-replicated genomic finding; it does not by itself spec- ify the social mechanism (a question outside the scope of population genetics proper) and should not be over-interpreted as establishing any particular account of the social interactions involved, which the genomic data cannot directly recover.

The genomic signature of matrilineal continuity in South Asia has important implications for models of the demographic processes through which IVC-related populations were transformed into the ancestral populations of historical South Asian communities. If the overwhelming majority of modern South Asian mitochondrial lineages derive from populations that have been in South Asia since the Holocene or earlier, then the major Bronze Age demographic events — the arrival of IVC-related populations in the third millennium, and the arrival of Steppe-ancestry populations in the second millennium — both involved predominantly male-mediated gene flow rather than mass migration of mixed-sex communities. This pattern of male-biased migration is consistent with the movement of mobile pastoral communities in which adult males predominate, and with the subsequent integration of these males into existing communities through intermarriage rather than the displacement of resident populations.

Chapter 84

The Bactria-Margiana Archaeological Complex and the

Central Asian Corridor

84.1 A Genetic and Material Way-Station

Definition EG.3: BMAC as an Intermediate Population The Bactria-Margiana Archaeological Complex (BMAC), a Bronze Age urban- agricultural culture centred on the river oases of southern Central Asia (modern Turk- menistan, Uzbekistan, northern Afghanistan, and Tajikistan) and broadly contemporary with the Mature Harappan phase, occupies a key intermediate position in the genomic and archaeological corridor connecting the Steppe with South Asia. Genome-wide anal- ysis of BMAC-associated ancient individuals (Narasimhan et al. 2019, the same study reviewed in Chapter 1) shows a population predominantly derived from Iranian-farmer- related and local Central Asian ancestry, with only a minor and chronologically late Steppe-ancestry component, indicating that the BMAC population was not itself the pri- mary vehicle of Steppe ancestry into South Asia but rather a culturally and, to a more lim- ited degree, genetically intermediate population through whose territory Steppe-derived groups subsequently moved. **Case Study EG.1: BMAC Material Culture in Indus Periphery Contexts. A small but consistent corpus** of BMAC-style material culture — distinctive compartmented bronze seals, a characteristic ceramic repertoire, and specific ornament types — has been recovered from sites at the northern and western margins of IVC distribution (including sites in the Quetta valley and at Shahr-i Sokhta in eastern Iran, itself a major site on the exchange route discussed in this chapter), documenting direct material contact between the BMAC and Indus Periph- ery zones independent of, though chronologically and geographically continuous with, the Shortughaï outpost of Proposition GEO.1. This BMAC-Indus Periphery contact zone is the most archaeologically visible segment of the broader Central Asian corridor through which the Steppe ancestry component that subsequently appears in post-2000-BCE

South Asian genomes (Finding A.2's qpAdm modelling) most plausibly travelled, making the BMAC an archaeologically tractable proxy for a demographic process whose South Asian endpoint is genomically well documented but whose specific intermediate route remains only partially resolved by direct ancient-DNA sampling.

The BMAC's role as a potential cultural and demographic buffer between the Steppe and the IVC has important implications for understanding the nature of Indo-Aryan language transmission. If proto-Indo-Aryan was the language of Steppe pastoralists who passed through or alongside the BMAC world before entering South Asia, the BMAC interaction zone may have served as a contact point where the migrating proto-Indo-Aryan speakers

encountered and incorporated BMAC cultural elements that are visible in the archaeology of the Gandhara Grave culture and perhaps also in the non-PIE elements of Vedic religious vocabulary. The BMAC itself was a multilingual zone, and the proto-Indo-Aryan speakers who passed through it would have been exposed to Iranian languages, BMAC languages of unknown affiliation, and possibly early forms of the languages that eventually gave rise to the Indo-Iranian branch.

Chapter 85

The Swat Valley Gandhara Grave Culture: A Genomic Bridge

85.1 Direct Ancient DNA From the Critical Transitional Window

Definition EG.4: The Gandhara Grave Culture Sample Series. The Gandhara Grave Culture (**also** termed the Swat Valley protohistoric cemeteries), dated to approximately 1200–800 BCE in the Swat and adjacent valleys of northern Pakistan, has yielded one of the most chronologically informative ancient-DNA sample series available for the Steppe-admixture process, because it falls squarely within the post-IVC, post-Steppe-arrival window that the Indus Periphery Cline samples discussed in Chapter 1 (dated predominantly before or at the threshold of Steppe contact) do not directly capture. Narasimhan et al. (2019) and subsequent analyses document Gandhara Grave individuals carrying a substantially higher proportion of Steppe-derived ancestry than the Indus Periphery Cline baseline, consistent with their position later in the admixture timeline reconstructed in

The Gandhara Grave culture's position as a possible progenitor of early Vedic communities implies that the transition from the IVC to the historical South Asian civilisations involved not a single demographic replacement event but a multi-stage process of demographic and cultural mixing. The IVC decline, the eastward dispersal of IVC-descended populations, the arrival of Steppe-ancestry groups through the Gandhara corridor, and the subsequent mixing of these populations in the Gangetic plain and beyond produced a demographic mosaic whose complexity is only beginning to be appreciated through ancient genomic analysis. The emergence from this mosaic of the historically documented South Asian civilisations — the Vedic tradition in the northwest, the post-Harappan archaeological cultures of Gujarat and Rajasthan, the Megalithic traditions of the Deccan and the south — represents the culmination of the IVC's transformation rather than its simple replacement.

Chapter 86

Finding EG.3:

A Chronologically Resolved Admixture Gradient. Considered together, the Indus Periphery Cline samples (pre-admixture baseline), the BMAC and Central Asian Steppe samples (the source populations), and the Gandhara Grave samples (a relatively early post-admixture population) form a chronologically ordered series that allows the admixture process to be tracked through actual ancient genomes at successive time points, rather than in- ferred solely from the indirect LD-decay dating method of Definition A.3 applied to modern populations. This direct ancient-DNA time series is among the strongest pieces of corroborat- ing evidence for the admixture chronology presented in Chapter 1, since it does not depend on extrapolating backward from present-day genomes but observes the ancestry transition directly in samples from the relevant historical window, substantially strengthening the ge- nomic engine's overall evidentiary standing relative to a hypothetical scenario in which only modern-population LD-decay estimates were available.

Chapter 87

Extended Case Study: The Shinde et al. Sample Curation

Debate

87.1 Sample Quality and the Single-Individual Inference Problem Revisited

Definition GEX.1: Endogenous DNA Yield at Rakhigarhi. The Rakhigarhi individual analysed in Shinde et al. (2019) yielded a comparatively low percentage of endogenous (ancient, as opposed to modern contaminant) DNA relative to many other published ancient-DNA studies from comparably aged remains, a consequence of the IVC region's hot, fluctuating-humidity burial environment being considerably less favourable to long-term DNA preservation than the cold or permafrost environments (Siberia, northern Europe) that have yielded some of the highest-quality ancient genomes elsewhere. The published analysis applied standard ancient-DNA authentication criteria (characteristic post-mortem damage patterns, mitochondrial contamination estimates) to establish that the retrieved sequence was authentic ancient DNA rather than modern contamination, but the lower overall coverage achieved necessarily widens the confidence intervals on derived ancestry-proportion estimates relative to higher-coverage ancient genomes, a technical point that did not feature prominently in the press-conference framing discussed in

The Rakhigarhi genome's significance extends beyond its contribution to population modelling to its role as a symbolic and political object in the context of Indian archaeology. The anticipation that preceded the publication of the genomic results — with both OIT proponents and migration-model supporters claiming in advance that the results would vindicate their position — illustrated the degree to which ancient DNA results had become a litmus test for competing historical narratives. The actual results, confirming IVC-related ancestry as a major South Asian component while finding no evidence of Steppe ancestry in the IVC population, satisfied neither extreme position completely and required the kind of nuanced interpretation that partisan accounts struggled to provide. The episode thus served as a case study in the communication challenges facing ancient genomics when its findings intersect with politically sensitive questions about national and ethnic identity.

Chapter 88

Finding GEX.1:

Coverage Limitations Compound, Not Replace, the Single-Sample Lim- itation. The single-genome limitation discussed at length in Chapter 2 (one individual can- not characterise a population's full ancestry variance) and the lower-coverage limitation dis- cussed here are independent sources of uncertainty that compound rather than substitute for one another: even if a future Rakhigarhi-region excavation yielded ten additional indi- viduals of comparable or better coverage, the original single Rakhigarhi genome's coverage limitation would remain a permanent feature of that specific publication's evidentiary con- tribution, simply diluted in importance by the larger dataset built around it. This is a useful general lesson for evaluating any single foundational ancient-DNA study in a still-developing regional dataset: coverage quality and sample-size adequacy are separate axes of evidentiary strength, and a study can be sound on one axis while remaining limited on the other.

Chapter 89

Extended Case Study: Comparative Steppe-Admixture Timing

Across South Asian Regions

89.1 Regional Heterogeneity in Steppe Ancestry Onset

Definition GEX.2: Differential Steppe Arrival Timing by Region Narasimhan et al. (2019)'s broader sampling beyond the single Rakhigarhi individ- ual documents that Central_Steppe_MLBA-related ancestry appears at measurably dif- ferent proportions and apparent onset times across different regions of the subconti- nent, with northern and northwestern sampled populations showing earlier and higher steppe-ancestry proportions than southern populations, a pattern consistent with a geo- graphically staged spread from a northwestern point of entry rather than a simultaneous subcontinent-wide admixture event. This regional heterogeneity is itself an important corrective to oversimplified "Aryan migration" narratives in either direction (complete absence or wholesale population replacement): the genomic data support a geograph- ically and temporally staged process of partial admixture, with substantial pre-existing population continuity in every sampled region, rather than either extreme. **Case Study GEX.1: The Southern India Outlier Populations. Certain present-day south- ern Indian** populations, particularly some scheduled-tribe groups with historically limited ad- mixture with surrounding caste-structured populations, show steppe-ancestry proportions at or near the lower bound of the sampled range, providing some of the closest currently available genomic proxies for pre-steppe-admixture South Asian population structure, though even these populations are not perfect proxies for any specific ancient population given the multiple intervening millennia of more localised admixture and drift. These populations have, accordingly, attracted disproportionate research and sampling attention as reference points for ancient-DNA modelling, a research-design choice with its own Tier 3 sensitivities given the populations' typically marginalised social status, a sensitivity the responsible literature in this area (Narasimhan et al. 2019; Reich 2018, popularisation) has generally sought to navigate through careful informed-consent and community-engagement protocols.

The admixture cline observed in present-day South Asian populations — with Steppe ancestry decreasing from northwest to southeast and from upper to lower social strata — has implications not only for the history of the Indo-Aryan language spread but for understanding the social mechanisms through which caste endogamy became established. If the early Indo-Aryan-speaking communities that brought Steppe ancestry into South Asia were socially dominant relative to the IVC-descended communities they encountered, the establishment of caste hierarchy may have consolidated a gradient of Steppe ancestry that was initially produced by geography and timing of admixture. The maintenance of this gradient

over the subsequent three millennia through caste endogamy would then represent one of the longest-sustained demographic stratification processes documented in the human past, with consequences for the present-day genomic structure of South Asian populations that are directly visible in the data.

Chapter 90

The Munda and Austroasiatic Substrate Hypothesis

90.1 A Third Language Family in the South Asian Mix

Definition EL.1: Munda as a Pre-Indo-Aryan, Pre-Dravidian Linguistic Layer. The Munda languages, a branch of the broader Austroasiatic family (whose other branches include Khmer and Vietnamese, with a homeland generally placed in Southeast Asia or southern China), are spoken today by relatively small, predominantly tribal populations across eastern and central India, geographically distant from the IVC's core distribution zone. Their presence in South Asia at all, given the family's otherwise Southeast Asian distribution, indicates at least one additional substantial population movement into the subcontinent independent of the Dravidian and Indo-Aryan language histories discussed in Chapters 6 and 7, and linguists working on Sanskrit's earliest attested vocabulary (most systematically Witzel, 1999) have identified a layer of loanwords and, more strikingly, syntactic and phonological features in the earliest Vedic Sanskrit that are diicult to derive from Indo-Aryan or Dravidian alone but find plausible cognates in reconstructed Proto-Munda or a related, possibly now-extinct, Austroasiatic language once spoken further west and north than the modern Munda distribution.

90.2 Implications for the IVC Language Question

Finding EL.1: A Third Candidate, With a Weaker Evidentiary Base Than Dravidian. The Munda or broader Austroasiatic hypothesis for the Indus script's underlying language has been proposed by a minority of specialists (most notably in early speculative form, though without the systematic sign-equivalence methodology Parpola applied to the Dravidian hypothesis in Chapter 6), but it has not attracted comparable sustained scholarly development, in part because the geographic distance between the IVC's core distribution and the modern and reconstructed ancient Munda-speaking zones (concentrated well to the east, in the Chota Nagpur plateau and adjacent regions) is considerably greater than the distance between the IVC and the modern Dravidian-speaking zone, even allowing for the Brahui outlier discussed in

The Munda languages, spoken by approximately nine million people in tribal communities across the Chota Nagpur Plateau, represent a branch of the Austroasiatic family whose presence in the South Asian interior has been interpreted as evidence of a prehistoric Austroasiatic expansion from Southeast Asia. The genomic signature of Munda-speaking populations — elevated levels of East Asian-related ancestry relative to other South Asian groups — is consistent with this migration hypothesis. The relevance of Munda to the IVC question arises from the proposal that Austroasiatic languages might have been spoken in parts of the

IVC's eastern distribution zone, and that substrate influences from Munda or proto-Munda might be detectable in early Sanskrit. Witzel's para-Munda substrate — proposed to account for non-Dravidian, non-Aryan loanwords in Rigvedic Sanskrit — has been identified by some scholars with a Munda-related language, though the evidence for this specific identification is debated. The geographic overlap between the proposed para-Munda substrate zone and the eastern IVC distribution makes the Munda hypothesis a relevant alternative or complement to the Dravidian substrate hypothesis. The resolution of the substrate question would benefit from advances in proto-Munda reconstruction currently underway, since more robust reconstructions of the proto-Munda phonological system would allow more rigorous testing of proposed loanword identifications in Old Indo-Aryan against the expected phonological signatures of Munda-origin borrowings, potentially providing the linguistic-historical triangulation needed to constrain the timing and geography of Austroasiatic expansion into the subcontinent.

Chapter 91

The Munda substrate evidence in Vedic Sanskrit is

nonetheless a genuine and independently documented finding in its own right, establishing that the linguistic landscape encountered by incoming Indo-Aryan speakers (Chapter 7) was more complex than a simple two-family (Indo-Aryan versus Dravidian) model assumes, a complexity this volume's Tier 2 discussion (Chapter 8) treats as a further reason for caution in any confident single-family assignment of the undeciphered Indus script.

Chapter 92

Substrate Vocabulary and the Linguistic Prehistory of the

Indus Region

92.1 Loanwords as Indirect Evidence of Contact Languages

Definition EL.2: The Substrate Vocabulary Method Historical linguists identify substrate influence — vocabulary, and more rarely gram- matical structure, absorbed into an incoming language from a pre-existing local language that the incoming language eventually displaced or marginalised — through words in the attested language (here, Vedic Sanskrit and its earliest commentarial tradition) that resist derivation from inherited Indo-European roots via the regular sound-correspondence rules of the comparative method, particularly when such words cluster semantically around domains (local flora and fauna, agricultural terms, place names) where substrate borrowing is cross-linguistically common. Kuiper (1991) catalogued several hundred such words in the Rigveda alone, a corpus subsequent scholars (Witzel, Southworth, and others) have refined, reassigning some items to Dravidian or Munda sources specifically and treating others as belonging to an unidentified, possibly extinct, substrate language or languages not securely assignable to any known family.

Proposition EL.1: An Unidentified Substrate as Indirect Evidence for the Indus Language. The existence of a residual category of Rigvedic substrate vocabulary not confidently assignable to Dravidian, Munda, or any other known language family has been invoked, speculatively, as indirect evidence that the IVC may have spoken a now entirely extinct language unrelated to any attested family — a logically available possibility that the present account's Tier 2 framework (Chapter 8) already accommodates under the language-isolate possibility of

The substrate vocabulary debate ultimately depends on the availability of well-reconstructed proto-languages for the proposed donor languages — primarily proto-Dravidian and proto-Munda — against which proposed loanwords in Old Indo-Aryan can be tested. Proto-Dravidian reconstruction is the more advanced of the two, owing to the greater documentation and historical depth of the Dravidian family. The Dravidian Etymological Dictionary of Burrow and Emeneau, supplemented by the Dravidian Etymological Dictionary of Krishnamurti, provides the reference framework for identifying Dravidian etymologies and detecting anomalous Old Indo-Aryan forms that may represent Dravidian loanwords. The degree to which these reconstructions can be extended to the period of IVC language remains uncertain, but the internal reconstruction of proto-Dravidian features from attested historical forms provides at least a methodological foundation for evaluating specific proposed loanwords.

Chapter 93

The substrate vocabulary

evidence, while genuine, cannot by itself discriminate between this extinct-language-isolate scenario and the alternative possibility that the residual substrate words simply reflect imperfect reconstruction or misattribution of genuinely Dra- vidian or Munda items, given the methodological diiculty of distinguishing borrowed sub- strate vocabulary from inherited vocabulary with an unusual but ultimately Indo-European etymology, a diiculty Kuiper's own successive revisions of his word list illustrate.

Chapter 94

River Names and Toponymic Evidence

94.1 Hydronymy as a Conservative Linguistic Fossil

Definition EL.3: The Toponymic Conservatism Principle. River names, as a cross-linguistic generalisation well documented outside South Asia (the persistence of pre-Indo-European river names across much of Europe is a classic instance), tend to be unusually resistant to replacement even when the surrounding population undergoes language shift, because river names function as stable geographic reference points transmitted across generations and across language-contact boundaries with comparatively little communicative cost to retaining the existing name. The river-naming pattern of the northwestern subcontinent, the IVC's core territory, has accordingly been examined for evidence of a pre-Indo-Aryan substrate naming layer that might illuminate the linguistic landscape the incoming Indo-Aryan speakers of Chapter 7 encountered. **Case Study EL.1: A Mixed and Inconclusive** Toponymic Record. Southworth's (2005) systematic survey of northwestern South Asian river names found a mixed pattern: some major river names (including names ultimately underlying the modern Indus, Jhelum, and other Punjab river names) have plausible Sanskrit or Indo-Aryan etymologies, consistent with either an original Indo-Aryan naming or a secondary Sanskritisation of pre-existing names, while a smaller number of river and place names resist confident Indo-Aryan deriva- tion and have been proposed, with varying degrees of confidence, as Dravidian, Munda, or unidentified-substrate survivals. The toponymic evidence, in Southworth's own assessment and in the subsequent literature, is suggestive but not individually decisive: place-name et- ymology is notoriously susceptible to folk-etymological reanalysis and secondary reinterpre- tation over the three-plus millennia separating the IVC from the present, and the toponymic record is accordingly treated in this volume as a corroborating rather than primary line of Tier 2 evidence, consistent with its treatment in the broader specialist literature.

The hydronymic evidence for pre-Aryan linguistic diversity in the northwest of the subcontinent is particularly significant because the northwest is precisely the region where the IVC's urban heartland was located and where Steppe-ancestry populations would have first entered South Asia. If river names in this region preserve traces of a linguistic stratum that predates both Indo-Aryan and Dravidian, this stratum is a plausible candidate for the language or languages of the IVC — not because IVC = Dravidian is thereby disproved, but because it opens the possibility that the northwestern IVC spoke a language that was neither Dravidian nor IE and that has left no surviving descendants. The archaeology of the IVC's northwest heartland, combined with the linguistic evidence for a non-IE, non-Dravidian substrate in the Rigvedic northwest, thus converges on a picture of pre-Aryan linguistic diversity that the simple equation of IVC language with proto-Dravidian cannot fully accommodate.

Chapter 95

Extended Case Study: Substrate Influence in Vedic Sanskrit

95.1 The Retroflex Consonant Question

Definition LEX.1: Retroflexion as a Proposed Substrate Marker. A frequently cited piece of evidence for early contact between Indo-Aryan and a pre-existing South Asian (most plausibly Dravidian or Munda) linguistic substrate is the presence of retroflex consonants (ṭ, ḍ, ṇ, and related sounds, articulated with the tongue tip curled back against the hard palate) in Vedic Sanskrit, a phonological

feature largely absent from other early Indo-European branches and from reconstructed Proto-Indo-European, but characteristic of Dravidian languages. Kuiper (1967, 1991) and subsequent scholars have argued that retroflexion's appearance and pro- gressive increase in frequency across the chronological layers of the Vedic corpus (from the earliest Rigvedic hymns to later Vedic prose) is best explained as a substrate-contact-induced sound change, acquired through contact with retroflex-rich Dravidian or Munda speakers as Indo-Aryan speakers moved into and through the subcontinent. **Note LEX.1: Why Retroflexion Is Suggestive but Not Decisive for the IVC Specifically.** While the retroflexion evidence is reasonably strong evidence for some form of substrate con- tact between early Indo-Aryan and pre-existing subcontinental languages, it does not by itself establish that the specific substrate language was the IVC's own language, as opposed to some other pre-Indo-Aryan subcontinental language unrelated to the IVC, or even a language spo- ken by a population that had no connection to the Indus cities at all. The retroflexion evidence is accordingly best classified, on the Tier framework of Definition 0.1, as solid Tier-2-internal evidence for substrate contact in general, while remaining silent on the further, specifically IVC-related identification that popular treatments often attach to it.

The substrate evidence in Rigvedic Sanskrit, taken together with the genomic evidence for male-biased Steppe ancestry admixture and the archaeological evidence for the gradual rather than abrupt transformation of IVC material culture, supports a model of language shift rather than population replacement as the primary mechanism of Indo-Aryan language spread in South Asia. In language shift scenarios, a numerically dominant population adopts the language of a socially or economically dominant minority, and the resulting language typically shows substrate influence from the abandoned language — precisely the pattern observed in Old Indo-Aryan. The social mechanisms driving language shift in Bronze Age South Asia are not directly observable, but comparative evidence from historically documented language shifts suggests that access to prestige goods, participation in exchange networks, and intermarriage with socially dominant groups can all motivate language adoption without requiring violent conquest or mass migration.

Chapter 96

Extended Case Study: The Munda Language Family as a

Third Substrate Candidate

96.1 An Underappreciated Alternative to the Dravidian Hypothesis

Definition LEX.2: Munda as a Structural Alternative The Munda languages, a branch of the Austroasiatic family spoken today by scattered tribal populations across eastern and central India, have been proposed (Witzel 1999; Southworth 2005) as an alternative or additional substrate source for certain loanwords in Vedic Sanskrit that do not fit comfortably into either an Indo-European or a Dravidian etymological derivation, including several agricultural and plant-name terms. Witzel's proposed "Para-Munda" substrate language, a hypothesised now-extinct Austroasiatic- related language once spoken more widely across the Gangetic plain and possibly into the IVC's eastern zone, would, if correct, complicate the binary Dravidian-versus-isolate fram- ing that dominates most popular discussion of the Indus script's likely language family (Chapters 6 and 7) by introducing a third serious candidate substrate population whose relationship to the IVC's own population and script remains, like the Dravidian hypothe- sis itself, entirely unproven at the Tier 1 genomic or Tier 2 decipherment level. **Proposition LEX.1: A Recommendation Against Premature Binary Framing. Given the existence of at** least three serious, non-mutually-exclusive linguistic substrate candidates for the pre-Indo-Aryan subcontinental linguistic landscape — Dravidian, Munda/Para-Munda, and an unspecified residual "language X" category that some loanword evidence resists as- signing to either named family — this volume recommends that future treatments of the Indus script's likely language ailiation resist the popular framing of the question as a binary choice between "Dravidian" and "unknown isolate," since the actual linguistic-substrate land- scape documented by historical linguists is considerably more heterogeneous than this binary suggests, and the IVC's own language could in principle belong to any of these families, to a now entirely extinct fourth family, or could itself be the source of loanwords into one or more of the surviving substrate candidates rather than being identical with any of them.

The temporal coincidence between the proposed Austroasiatic migration into South Asia and the proposed Indo-Aryan migration — both occurring broadly during the second millennium BCE — raises the possibility that the demographic landscape of the South Asian subcontinent underwent a more complex transformation during this period than is captured by models that treat the two migrations separately. If proto-Munda-speaking populations were moving westward from Southeast Asia at roughly the same time as proto-Indo-Aryan-speaking populations were moving southward from the Steppe, and if both were encountering the descendants of IVC populations moving eastward from the Indus heartland, the

resulting contact situation would have been one of exceptional linguistic and demographic complexity — a scenario that the archaeological and genomic evidence is beginning to document but that the textual evidence, which begins only with the Rigveda, preserves only indirectly through substrate traces.

Chapter 97

Place-Name Evidence and Toponymic Layering

97.1 What River and Place Names Can Suggest About Substrate Populations

A further line of linguistic evidence bearing on the pre-Indo-Aryan substrate question discussed in Chapters 77 and 78 comes from toponymy: the observation, made across many regions of the world where a documented language replacement has occurred, that river names and other major geographic toponyms often persist across language-replacement events even when the bulk of the everyday vocabulary does not, because place names are typically borrowed wholesale by incoming populations from existing local usage rather than being freshly coined. Some scholars have accordingly examined the etymology of major North Indian river names for evidence of a non-Indo-Aryan substrate origin, with mixed and generally inconclusive results: a number of major river names admit plausible Indo-Aryan etymologies, while a smaller number resist confident Indo-Aryan derivation without thereby yielding an unambiguous alternative etymology in any of the candidate substrate languages discussed above. The toponymic evidence, in short, neither strongly supports nor strongly undermines the broader substrate-contact case built primarily on the retroflexion and loanword evidence discussed earlier in this Part, and is presented here mainly as an illustration of the general evidentiary principle, recurring throughout this study's linguistic chapters, that individual categories of indirect linguistic evidence for the IVC's language situation tend to be individually weak and only cumulatively, and still incompletely, suggestive of a genuine but currently unidentifiable substrate presence.

and Hydraulics

The toponymic invisibility of the IVC in later South Asian textual traditions contrasts markedly with the situation in Mesopotamia, where ancient Sumerian city names survived the transition to Akkadian-speaking dominance and are documented in cuneiform records spanning more than two millennia. The contrast may reflect genuinely greater linguistic discontinuity in South Asia, where the IVC's language — whatever it was — was eventually replaced by Indo-Aryan languages in the northwest and by Dravidian languages in the south, leaving few bilingual communities that might have preserved IVC toponyms in the later textual record. Alternatively, IVC city names may have been adopted into Indo-Aryan or Dravidian phonological systems in forms so transformed as to be no longer recognisable as IVC in origin, a process of phonological assimilation that would be consistent with the substrate evidence for extensive lexical borrowing from pre-Aryan languages into Old Indo-Aryan.

Chapter 98

Metallurgy and the Bronze Age Economy of the Indus

98.1 Copper Sources and the Absence of True Tin Bronze

The IVC's metallurgical record presents a paradox relative to its contemporaries in Mesopotamia and the Aegean: the civilisation is conventionally classified as Bronze Age, yet true tin-bronze (copper alloyed with 8–12Copper-Alloy Spectrum. Archaeometallurgical analyses of Harappan metal artefacts (Agrawal 1971; Kenoyer & Miller 1999) identify at least four distinct alloy classes in use during the Mature Harappan period: (a) unalloyed or near-unalloyed copper, the most common class, used for everyday tools (chisels, knives, fish-hooks) and de- rived primarily from the Khetri copper belt of Rajasthan and from Omani/Arabian sources reachable via Gulf trade; (b) arsenical copper (1–3as a deliberate alloying choice and, in some assemblages, as an incidental consequence of smelting arsenic- bearing copper ores, complicating the inference of intentionality; (c) genuine tin bronze, concentrated disproportionately in a minority of sites and object classes (notably mirrors, ceremo- nial vessels, and the Mohenjo-daro 'dancing girl' figurine), with tin sourced most plausibly from Afghan (Helmand region) or Central Asian deposits given the absence of significant tin ore in the Indus core zone itself; (d) lead-copper alloys, used selectively for casting appli- cations where lower melting point was advantageous. The patchy and non-uniform distribu- tion of tin bronze across the corpus indicates that bronze was a prestige or specialist material rather than the civilisation's standard utilitarian metal, a pattern that distinguishes the IVC's metal economy from the more bronze-saturated assemblages of contemporary Mesopotamia. **Finding MET.1: Lost-Wax Casting and the Limits of the** Evidence. The Mohenjo-daro 'dancing girl' bronze figurine, cast using the lost-wax (cire perdue)

technique, is frequently cited as evidence of sophisticated IVC casting technology, and the technique is well attested by associated crucible and mould fragments at several sites. However, the lost-wax corpus is nu- merically small relative to the much larger assemblage of simple open-mould and hammered copper tools, and inferring a generalised "advanced metallurgical tradition" from a handful of prestige castings risks the same evidentiary error — generalising from preservation-biased exceptional finds to civilisation-wide capability — discussed in the script-literacy debate of Chapter 26. The honest characterisation is that the IVC possessed lost-wax casting capability among a specialist subset of metalworkers, not that this was the typical production mode for the metal economy as a whole.

98.2 The Khetri Copper Belt and Procurement Geography

Case Study MET.1: Ganeshwar-Jodhpura and the Copper Hoard Question. The Ganeshwar-Jodhpura cultural complex of northeastern Rajasthan, chronologically overlapping with and partly predating the Mature Harappan phase, has produced large quantities of copper objects (arrowheads, harpoons, antennae swords) in a regional style distinct from classic Harappan metal typology. The relationship between this complex and the IVC proper is debated: some scholars (Agrawal & Kharakwal 2003) treat Ganeshwar-Jodhpura as the IVC's principal supply zone for Khetri copper, with the regional metal-working style representing a distinct but economically linked population; others caution that the typological distinctiveness argues for a degree of cultural autonomy inconsistent with simple characterisation as an IVC "periphery." This question intersects with the broader Tier 3 caution of **Definition 0.1: assigning Ganeshwar-Jodhpura unambiguously to an "Indus sphere" risks importing** political stakes about the civilisation's territorial reach that the metallurgical evidence alone does not settle.

98.3 Comparative Note: The IVC in the Pan-Eurasian Bronze Age Network

Proposition MET.1: Convergent versus Diffused Metallurgical Practice. The methodological caution developed in the companion monograph on wheel technology in the fourth- millennium Eurasian network — that geographically dispersed appearance of a technology need not imply a single point of origin with subsequent diffusion, given that taphonomic and sampling biases can produce an illusory diffusion gradient where none existed — applies with equal force to Bronze Age metallurgical practice. The appearance of arsenical copper alloying in geographically separated zones (the Indus, the Iranian plateau, the Caucasus) at broadly overlapping periods is consistent with both a transmitted-technique scenario and an independent-discovery scenario, since arsenical enrichment is also a plausible incidental outcome of smelting certain naturally arsenic-bearing copper ores without any deliberate alloying knowledge being transmitted at all. As in the wheel case, the correct null hypothesis is multiple independent low-probability events rather than a single innovation event, until evidence of a specific, datable contact vector is established for a specific alloy tradition.

Chapter 99

Ceramic Technology and the Indus Pottery Tradition

99.1 The Black-on-Red Painted Tradition

Definition CER.1: The Standard Harappan Ceramic Assemblage The Mature Harappan ceramic tradition is characterised by a wheel-thrown, red- slipped ware decorated with black painted designs — geometric motifs, pipal-leaf pat- terns, fish-scale bands, and

occasionally figurative scenes (peacocks, bulls) — fired in a generally oxidising kiln atmosphere. The standardisation of vessel forms (the perforated cylindrical jar, the dish-on-stand, the S-shaped jar) across sites separated by over a thou- sand kilometres is, alongside the brick and weight standardisation discussed in Definition T.1 and Proposition MC.1, among the strongest evidence for a shared technological and stylistic convention spanning the IVC's full territorial extent. Petrographic and chemical (INAA, ICP) analyses of clay fabrics indicate that most pottery was produced locally at or near consumption sites from regionally available clays, with standardisation achieved through a shared technical and stylistic tradition (a 'community of practice') rather than through centralised production and long-distance ceramic transport, which was reserved for a smaller class of distinctive or luxury wares. **Finding CER.1: The Potter's Wheel and Production Throughput. The Harappan pot- ter's wheel,** inferred from the characteristic horizontal throwing-rings visible on excavated vessel interiors, represents a continuous-rotation kick- or stick-spun apparatus rather than the slower, intermittently-spun "tournette" (turntable) used in some other Bronze Age tradi- tions for finishing rather than primary forming. This distinction matters because continuous- rotation wheel-throwing permits substantially higher production throughput per potter than tournette-finishing of hand-built vessels, and the resulting standardisation of wall thickness and rim profile across the Harappan corpus is consistent with specialist, high-volume craft production of the kind documented ethnoarchaeologically among practising South Asian potter communities, rather than household-level production for immediate domestic use.

99.2 Kiln Technology and Firing Regimes

Case Study CER.1: The Harappa Kiln Complex. Excavations at Harappa have identified updraught kiln structures with separate firing and ware chambers, permitting more controlled and higher-temperature firing than open-pit or bonfire firing methods. Experimental firing replications (Kenoyer 1992, 1997) suggest that the standard red-ware oxidising firing was achieved at temperatures in the range of approximately 800–950°C, with the consistent red colouration achieved through both clay iron-oxide content and controlled access of oxygen during the cooling phase — a firing regime requiring accumulated practical knowledge of

kiln draught management rather than being a passive outcome of any particular clay composition.

99.3 Comparative Network Position: Indus Ceramics and the Wider Eurasian Horizon

Proposition CER.1: Local Standardisation versus Network Diffusion. The companion mono- graph on the pan-Eurasian ceramic network of the fourth-to-third-millennium horizon doc- uments a broader pattern in which regional ceramic traditions achieve internal standardisa- tion through dense local interaction networks (workshops, apprenticeship lineages, market exchange of finished vessels) without requiring long-distance diffusion of techniques from a single point of origin. The IVC ceramic tradition fits this pattern: its standardisation operates at the scale of the IVC's own interaction sphere, and while there are documented contact-zone ceramic exchanges (Indus-style pottery at Gulf sites such as Ras al-Jinz, attesting maritime trade contact discussed further in Chapter 31), there is no evidence requiring the Harappan tradition's internal stylistic coherence to be explained by transmission from, or to, any ex- ternal Bronze Age ceramic tradition. The appropriate inferential caution — standardisation indicates a shared internal community of practice, not necessarily external technological de- pendency — generalises across both the ceramic and metallurgical case studies of this Part.

The ceramic technology of the Indus tradition achieves a standardisation of form and firing temperature that implies specialised production in dedicated kilns rather than household manufacture. Wheel-thrown pottery, fired at temperatures between 900 and 1050 degrees Celsius in reducing or oxidising atmospheres, produced the characteristic buff-to-red wares of the Mature Harappan period with a consistency of wall thickness and vessel profile that indicates professional potters working to established specifications. The decoration, where present, is applied in standardised motifs — fish-scale patterns, intersecting circles, pipal leaves — that recur across geographically distant sites and provide one of the clearest material expressions of the shared cultural vocabulary that unified the Mature Harappan urban system. The Late Harappan ceramic record, with its introduction of new forms, motifs, and fabric types, provides the clearest stratigraphic marker for the cultural transformations of the decline phase.

Chapter 100

Wheel Technology and Wheeled Transport in the IVC

100.1 The Terracotta Cart Model Corpus

Definition WHL.1: The Harappan Toy-Cart Evidence Base. The primary direct evidence for wheeled vehicles in the IVC is a substantial corpus of terracotta model carts and detachable terracotta wheels, recovered in large numbers from Mohenjo-daro, Harappa, Chanhudaro, and other Mature Harappan sites. These models depict a two-wheeled ox-cart with a flat or slightly curved bed, consistent in basic form with the bullock-cart types still in everyday use in the rural subcontinent today — among the longest continuities of vehicle form documented anywhere in the archaeological record. The models show solid disc wheels rather than spoked wheels, consistent with the broader Bronze Age pattern in which spoked wheels are a later (predominantly second-millennium) development associated with lighter, faster vehicles such as chariots. **Finding WHL.1: What Toy Models Can and Cannot Establish.** Terracotta cart models are strong evidence that wheeled vehicles, in roughly the depicted configuration, were a fa- miliar part of Harappan material culture — familiar enough to be reproduced as children's toys or votive objects in quantity. They are weaker evidence for the vehicles' precise struc- tural engineering (axle diameter, wheel-hub tolerance, load capacity), since toy models are not built to the same structural specifications as functional full-size vehicles and may sim- plify or schematise features not relevant to a toy's function. Inferences about Harappan cart engineering performance — as opposed to Harappan cart existence — accordingly require in- dependent evidence: wheel-rut measurements from settlement contexts (where preserved), full-scale wooden vehicle remains (extremely rare due to organic preservation bias, discussed further below), and ethnoarchaeological analogy to historically documented bullock-cart con- struction in the same general region.

100.2 Wheel-Rut Evidence and Gauge Estimation

Case Study WHL.1: Banawali and Kalibangan Wheel-Rut Traces. Excavations at Banawali and Kalibangan have reported parallel groove features in street surfaces interpreted as cart wheel-ruts, with measured gauge (the spacing between the two ruts of a single passing vehicle) reported in the broad range consistent with values measured at other Bronze Age sites across Eurasia. As discussed in the companion monograph on the eurasiatic wheel network, gauge measurements of this kind cluster around values plausibly set by the biomechanical constraint of paired draught-animal body width rather than by any specific engineering standard transmitted between cultures, and the IVC gauge data, where available, are consistent

with this biological-constraint interpretation rather than requiring inference of contact-based standard transmission from any specific external Bronze Age vehicle tradition.

100.3 The Organic Preservation Problem and Its Implications for the IVC Case

Proposition WHL.1: Applying the Wood-Preservation Bias Correction to the Indus Record. **The** companion monograph's central methodological result — that wood preservation rates differ by orders of magnitude between anoxic burial environments and the aerobic, often arid conditions typical of open settlement sites — applies directly to the IVC case and explains why no full-scale wooden cart axle or wheel has survived from any Mature Harappan settlement despite the strong terracotta-model and wheel-rut evidence for the technology's presence. The IVC's predominantly seasonally arid, periodically flooded alluvial settlement environments are particularly unfavourable for organic

preservation relative to the northern- European waterlogged contexts (such as the Ljubljana Marshes, source of some of the best- preserved Eurasian Bronze Age wooden wheels) discussed in the companion study. The absence of preserved Harappan wooden wheels is accordingly uninformative about whether, or when, wheeled-vehicle technology was present in the Indus zone, and should not be read as evidence either for or against any particular chronology of adoption; the terracotta and wheel-rut evidence base, not the (absent) organic evidence base, is the relevant data for the IVC question, and that evidence base places wheeled ox-cart transport solidly within the Ma- ture Harappan technological repertoire.

Chapter 101

Lapidary Technology and Long-Distance Bead Trade

101.1 Carnelian Bead Production at Chanhu-daro and Dholavira

Definition LAP.1: The Long Carnelian Bead and the Cambay Technique. The IVC's lapidary craft achieved international renown, in antiquity and in modern archaeometric study alike, for the production of long, biconically perforated carnelian beads — some exceeding 10 cm in length — requiring a drilling technique capable of producing a straight perforation through extremely hard, brittle stone over an exceptional length-to-diameter ratio. Production debris at Chanhu-daro and, in later (post-Harappan but technologically continuous) periods at Khambhat (Cambay) in Gujarat, documents a multi-stage process: nodule selection, controlled heating to enhance the stone's natural red colouration and workability, rough flaking, grinding to final shape, and drilling using specialised stone or, in some interpretations, copper-tipped drills with an abrasive slurry, requiring (by experimental replication estimates) many hours of skilled labour per finished long bead. **Finding LAP.1: Beads as Evidence for the Meluhha Trade Identity. Harappan-style carnelian and etched beads** have been recovered from Mesopotamian contexts including the Royal Cemetery of Ur, and are among the strongest material correlates for identifying "Meluhha" — the toponym appearing in Mesopotamian cuneiform texts for a distant trading partner gen- erally identified with the Indus region — with the IVC specifically, alongside the Indus-style seals found at Gulf sites discussed in Chapter 31. The bead evidence is methodologically valuable because the etched carnelian bead technique (alkali-etched white designs on a red ground) is suiciently distinctive and labour-intensive that independent invention at mul- tiple sites is implausible, making findspot distribution a reasonably reliable indicator of an actual exchange network rather than of convergent local craft development — a contrast with the cautionary convergence arguments developed for metallurgy (Proposition MET.1) and ceramics (Proposition CER.1) above, illustrating that the appropriate null hypothesis (dif- fusion versus independent invention) is technology- and context-specific rather than a fixed methodological default.

101.2 Stoneware Bangles and Faience

Case Study LAP.1: The Mohenjo-daro Stoneware Bangle Mystery. A small, technologically anomalous class of Harappan ceramic objects — stoneware bangles, fired at suiciently high temperature to achieve a near-vitrified, glass-like fabric distinct from the standard earthenware tradition — has resisted full technical replication, with debate continuing over the precise firing temperature and atmosphere required and over whether production was restricted

to a small number of specialist workshops (the concentration of finds and production waste at Mohenjo-daro suggests centralised, restricted production, in contrast to the broadly distributed

standard pottery production model of Definition CER.1).

Lapidary technology in the IVC achieved levels of precision and standardisation with no contemporary parallel. The production of long barrel-shaped carnelian beads — some exceeding ten centimetres in length and drilled to tolerances measured in fractions of a millimetre — required systematic mastery of carnelian's material properties and a production sequence reconstructed experimentally by Kenoyer. The sequence involves initial heat treatment, rough shaping, fine shaping by grinding, drilling from both ends, and final polishing — conducted at specialised production centres from which finished beads were distributed across the IVC network and exported to Mesopotamia. Etched carnelian beads, produced by applying a sodium-based bleaching agent to selected areas before firing, created white geometric patterns on the red ground and represent a further level of technological sophistication. These beads have been recovered from the Royal Cemetery of Ur, confirming their role as prestige trade goods moving through the Meluhha connection. The distribution of carnelian bead types across IVC sites suggests a structured trade system in which certain bead forms functioned as markers of status or group identity. Steatite microbeads, produced in quantities implying industrial-scale manufacture at sites like Chanhu-daro, represent the other end of the bead production spectrum: these tiny objects, some less than a millimetre in diameter, required drilling technology of extraordinary precision and were produced and traded in quantities suggesting a mass-market function within the IVC ornament economy.

Chapter 102

Hydraulic Engineering and Water Management

102.1 Urban Drainage Systems Revisited

Definition HYD.1: The Three-Tier Harappan Drainage Hierarchy Building on the basic description of Mohenjo-daro's drainage in Case Study MC.1, comparative study across multiple Mature Harappan sites identifies a consistent three- tier hierarchy: (a) household-level soak-pits and small drains carrying wastewater from individual residences to (b) street-level covered brick drains running beneath or along- side the main thoroughfares, which in turn fed (c) larger collector drains carrying com- bined wastewater to disposal points outside the settlement core. The presence of inspec- tion holes (sumps with removable covers, permitting periodic clearing of accumulated sediment) at regular intervals along the street drains indicates that the system was designed for routine institutional maintenance rather than being a one-time construction subsequently left unmanaged, implying an ongoing municipal or quasi-municipal labour allocation for drain upkeep that is itself a significant, if indirect, piece of evidence for or- ganised civic administration (cf. Finding T.1's paradox of administrative capacity without legible administrative text).

102.2 Well Technology and Domestic Water Supply

Finding HYD.1: The Ubiquity of the Private Well. Mohenjo-daro alone is estimated, on the basis of well density in excavated areas (Jansen 1989), to have had over 700 wells across the full site, a figure that implies private or small-group well access, rather than centralised public water distribution, was the dominant model for Harappan domestic water supply — a structural contrast with the centralised reservoir model documented for Dholavira (Case Study GEO.1), reflecting Dholavira's distinct hydrological constraints (absence of a perennial river) relative to the Indus-trunk cities. Harappan wells are typically built of wedge-shaped (radially tapered) bricks specifically manufactured to produce a true circular well shaft, a specialised brick form distinct from the standard rectangular brick of Definition T.1 and itself a further instance of the civilisation's capacity for standardised, purpose-specific manufactured components.

102.3 Agricultural Water Management

Proposition HYD.1: Inundation Agriculture versus Engineered Irrigation. Direct archaeological evidence for engineered canal irrigation in the Mature Harappan core zone is sparse

relative to the strong evidence for urban water management discussed above, and the dominant scholarly reconstruction (Possehl 2002; Wright 2010) favours a primarily inundation-based agricultural regime — exploiting the natural seasonal flooding of the Indus and Ghaggar-Hakra systems described in Definition GEO.1 to water and naturally fertilise riverine fields — over large-scale engineered canal networks of the kind documented in contemporary Mesopotamia. This distinction matters for the civilisational-collapse debate of Chapter 10: a civilisation dependent on natural inundation timing and volume is more directly and immediately vulnerable to the kind of monsoon-driven hydrological disruption documented in the palaeoclimate proxy record than one with substantial engineered buffering capacity, reinforcing rather than undermining the plausibility of the climate-stress component of the decline literature, even as Chapter 24 and related discussions caution against treating climate as a monocausal explanation.

Hydraulic engineering at IVC urban sites encompassed a range of technologies applied to the management of water for drinking, sanitation, and possibly ritual purposes. The well technology documented at Mohenjo-daro — with over 700 wells estimated across the full site extent based on density observed in excavated areas (Jansen 1989) — reflects a systematic solution to the problem of potable water supply in a large urban centre. The wells were constructed with carefully tapered cylindrical shafts of wedge-shaped fired bricks that interlocked to provide structural stability without mortar. The drainage system is equally remarkable: covered drains of fired brick running beneath the main streets collected wastewater from individual houses through ceramic pipe connections. The regularity with which drain connections were incorporated into domestic architecture argues for planning regulations of some kind, though the administrative mechanism by which such standards were enforced is not recoverable. At Dholavira, a series of large water storage reservoirs cut into the natural rock and connected by channels to capture monsoon runoff represents an adaptation to the more arid conditions of the Gujarat interior. The Dholavira reservoir system, estimated to have had a total storage capacity substantially exceeding the site's immediate daily needs, implies sophisticated hydrological planning to manage inter-seasonal variability. The contrast between the well-based water supply of the Indus heartland sites and the reservoir-based system of Dholavira illustrates the degree to which IVC hydraulic engineering was adapted to local hydrological conditions rather than simply replicating a single canonical template across the entire urban system.

Chapter 103

Numeracy, Weights, and Quantitative Administration

103.1 The Binary-Decimal Weight System Revisited

Definition NUM.1: The Structure of the Indus Weight Series. Building on the basic weight standardisation documented in Definition T.1, detailed metrological analysis (Hemmy 1931; Miller 2013) of the cubical chert weight corpus identifies a weight series following a ratio se- quence of 1, 2, 4, 8, 16, 32, 64 in the lower denominations (a binary doubling structure) tran- sitioning to a decimal multiplication pattern (160, 200, 320, 640) at higher denominations, with the base unit corresponding to approximately 0.856 grams. This hybrid binary-then- decimal structure, consistent across sites separated by hundreds of kilometres with a coei- cient of variation among excavated weights of the same nominal class typically under 2–3centrally-conceived (if not necessar- ily centrally-enforced) administrative standard operating across the full Mature Harappan territorial extent. **Finding NUM.1: What the Weight System Implies About** Numerical Cognition. The binary-to-decimal structural transition in the Harappan weight series implies that Harappan quantitative administration operated with a numerical system capable of representing both binary-doubling and decimal-multiplicative relationships, whether or not this numerical ca- pacity was represented in the Indus script through dedicated numeral signs (a question bear- ing on, but distinct from, the script decipherment debate of Chapters 26 and 25). The practical administrative implication is that whoever used these weights — plausibly the same merchant or administrative class responsible for the sealing practices of Finding SEAL.1 — required no special numerical training beyond facility with a system of nested multiples, a relatively low cognitive barrier to entry consistent with broad participation in the weighing-and-sealing economy rather than a narrow specialist priesthood-administered system.

103.2 Comparative Closing Note for Part: Technology as Convergent Evidence

Note TECH.1: The Cumulative Pattern Across the Technology Chapters. Read together, the metallurgical, ceramic, vehicular, lapidary, hydraulic, and metrological evidence surveyed in this Part converges on a consistent civilisational profile: high craft standardisation, sophisti- cated but not maximal technological investment (bronze as a minority prestige alloy rather than the standard metal; inundation rather than engineered-canal agriculture), strong evi- dence of organised civic administration operating through material and infrastructural chanThe Indus Enigma nels (drains, wells, weights, standardised bricks) without requiring

legible textual adminis- tration to be inferred, and a technological repertoire that is best explained, case by case, by a mixture of internal innovation, regional adaptation, and selective long-distance exchange (lapis lazuli, tin, carnelian beads) rather than by any single overarching diffusion or isola- tion narrative. This pattern is consistent with, and reinforces, the broader epistemic posture recommended throughout this volume: a civilisation whose material achievements are well- documented and impressive on their own terms, and whose more contested questions (script, language, ethnic continuity) remain separable from, and are not resolved by, the technologi- cal record reviewed here.

Directions

The quantitative dimensions of IVC administration extend beyond the weight and measure system to encompass evidence for standardised accounting and numerical record-keeping. The seal-and-sealing system implies a mechanism for tracking the movement and ownership of goods that required some form of numerical reckoning, even if specific quantities were not recorded on durable media. The regularity of certain ceramic forms — large perforated jars and standardised goblets — has been interpreted as evidence of standardised volume measures for liquids and grains, complementing the solid-weight system. The IVC's quantitative achievements in architecture — the consistent 4:2:1 brick ratio, regular street widths, careful levelling of building platforms — imply geometric and measurement capacities whose practical basis in tools (plumb bobs, measuring rods, set squares) is occasionally confirmed by physical finds. The intersection of quantitative administration with the script remains the central unsolved problem: if the Indus script encodes numerical information, its decipherment would likely reveal the quantitative dimensions of IVC economic administration in the way that proto-cuneiform tablets from Uruk reveal the commodity accounting of early Mesopotamian urban centres. The comparison is instructive not only as an analogy but as a contrast: the Uruk administrative system left tens of thousands of tablets, while the IVC's administrative traces consist primarily of a few thousand seal impressions averaging five signs each — a difference in archival density that may reflect either a less intensive administrative system or the near-total loss of the medium on which more extensive records were kept.

Chapter 104

Open Question: Was the IVC a State?

104.1 Revisiting the Heterarchy Debate in Light of the Full Evidentiary Record

Definition OQ.1: The Cumulative Case Reassembled Having now reviewed the genomic, linguistic, archaeological, computational, material-cultural, comparative, historiographic, religious, and site-specific evidence as- sembled across this volume, the state-versus-heterarchy question first posed in Defini- tion CC.2 can be restated with the benefit of the full evidentiary record: standardisa- tion evidence (weights, bricks, seal iconography, urban grid orientation) is extensive and points toward strong inter-regional coordination; monumentality evidence (palaces, royal tombs, dynastic inscriptions) is essentially absent; violence and fortification evi- dence points toward a comparatively low level of organised inter-polity coercion; and mortuary evidence points toward comparatively modest status differentiation. No single piece of this evidence is individually decisive, but their joint pattern is more consistent with some form of heterarchical or distributed-authority organisation, achieving coordi- nation through shared convention, merchant and craft-guild institutions, and possibly religious authority, than with a centralised territorial monarchy of the Mesopotamian or Egyptian type.
Note OQ.1: Why This Conclusion Remains Provisional. This volume's authors are conscious that the heterarchy reading, while currently the better-supported position on the assembled evidence, depends critically on the undeciphered status of the Indus script: a successful decipherment revealing royal names, administrative titles, or tribute records would immediately and substantially revise this assessment, since the heterarchy reading is in significant part an inference from the absence of evidence for centralised kingship rather than from positive evidence for any specific alternative governance structure, and absence-of-evidence arguments are, as repeatedly emphasised throughout the present account, structurally weaker than positive findings. The state-question chapter is accordingly presented as this volume's best current synthesis rather than as a settled conclusion, and readers should weight it accordingly against the more rigorously demonstrated findings of Parts I through IV.

The question of IVC political organisation depends on definitional choices that the archaeological evidence alone cannot resolve, as noted in Chapter 39. The distinction between Chapter 39 and this open question chapter lies in the focus here on what future evidence or methodological advances could resolve the debate, rather than on reviewing existing arguments. The most direct evidence for or against centralised coercive governance would come from the identification of administrative archives — texts recording commands, obligations, or redistributions emanating from a central authority — or from the discovery of mass graves, weapon deposits, or destruction layers associated with inter-polity conflict. The absence of such evidence after more than a century of excavation at major IVC sites is itself a significant data point, suggesting that if centralised coercive governance existed, its material traces

were either perishable or archaeologically invisible in the ways that have been systematically explored to date.

Chapter 105

Open Question: A Multi-Causal Reassessment of Urban

Decline

105.1 Integrating Climate, Trade, and Internal Dynamics

Definition OQ.2: A Layered Causal Model. The decline of Mature Harappan urbanism, examined piecemeal through the climate evidence of Chapter 10, the migration-timing evidence of Chapter 11, and the regional-diversification evidence of Chapter 62, is best synthesised not as a single cause but as a layered process operating on different timescales: a slow-acting structural vulnerability (the Ghaggar-Hakra system's dependence on monsoon-fed rather than glacier-fed water, Definition GEO.1) interacting with a discrete climatic shock (the 4.2 ka aridification event) to produce differential regional stress, compounded by a probable disruption to the long-distance trade networks documented in Chapter 31 (Mesopotamian textual references to Meluhha become markedly less frequent after approximately 1900 BCE, a decline plausibly linked to both the IVC's internal transformation and to contemporary Mesopotamian political fragmentation reducing demand), and unfolding over a timescale of two to three centuries rather than as a sudden collapse — a tempo confirmed by the staggered regional successor-culture pattern of Finding GZ.2. Proposition OQ.1: Decline as Transformation Rather Than Collapse. Framed this way, the conventional language of

"collapse" or "decline," while retained throughout this volume for continuity with the established literature, somewhat overstates the discontinuity involved: population did not vanish from the former IVC territory, agricultural production continued (in transformed regional patterns, as the archaeobotanical evidence of Chapter 21 indicates), and craft traditions persisted with modification into the Late Harappan successor cultures of

The multi-causal framework for IVC decline, while methodologically sound, risks becoming a way of avoiding the question of relative causal weight — of which factors were primary and which were secondary amplifiers. The evidence currently available does not permit a confident ranking of the proposed causes, but it does suggest some constraints. The near-simultaneity of the decline across geographically diverse regions of the IVC — from the Indus heartland to Gujarat to the Ghaggar-Hakra zone — is more consistent with a widely distributed stressor (climate) than with internal political or economic factors that would be expected to affect different regions at different rates. This does not foreclose the possibility that internal factors were important, but it suggests that any complete account of the IVC decline must explain the geographic breadth of the transformation, which internal factors alone, operating on a polycentric and distributed governance system, would not obviously produce.

Chapter 106

What ended was specifically the urban,

civic-infrastructure, and long-distance- trade-integrated complex documented in Part VII — a transformation in social and economic organisation rather than a demographic or cultural extinction event, a framing more con- sistent with the genomic continuity evidence of Chapter 27 than the older "disappearance" narrative that this more integrated, multi-engine account supersedes.

The regional diversification of the Late Harappan period represents not only a cultural transformation but a demographic reorganisation whose geographic expression is only beginning to be understood through the combination of settlement survey, archaeobotanical evidence, and ancient DNA data. The eastward dispersal of populations into the Gangetic plain, documented in the spread of Late Harappan ceramic traditions and in the appearance of rice agriculture in the eastern piedmont zone, suggests a large-scale movement of people that would have brought IVC-related cultural and genetic heritage into contact with the populations of the eastern subcontinent for the first time. The demographic consequences of this interaction — the mixing of IVC-descended populations with the Ancient Ancestral South Indian populations of the eastern and southern subcontinent — may be visible in the present-day genomic structure of South Asian populations, though the ancient DNA evidence needed to document it directly is not yet available.

Chapter 107

Open Question: What Would Decipherment Actually

Require?

107.1 A Realistic Assessment of the Remaining Paths

Definition OQ.3: Three Scenarios for Future Progress. Drawing together the computational findings of Part IV and the comparative decipherment evidence of Chapter 40, three scenarios, not mutually exclusive, represent the realistic paths by which the current impasse could be broken. Scenario one, a new bilingual find: the discovery of an Indus inscription paired with a known script (most plausibly a cuneiform or proto-Elamite bilingual at a trade-contact site, given the documented Meluhha exchange relationship of Chapter 31) would supply the ex- ternal phonological anchor that Definition CC.3 identifies as the historically decisive factor in every successful prior decipherment; no such find has yet been reported despite a century of excavation, but the comparative base rate for bilingual discovery in other decipherment cases (the Rosetta Stone, found after millennia, by chance, during military engineering work) shows that such finds are not predictable from the absence of one to date. Scenario two, corpus expansion: continued excavation, particularly in less-explored zones of the Ghaggar-Hakra corridor and at sites not yet fully excavated (a substantial fraction of even well-known sites, including portions of Mohenjo-daro, remain unexcavated or inaccessible), could in principle expand the corpus toward the scale that has historically been associated with successful decipherments, though corpus size alone, on the Proto-Elamite evidence of Note CC.1, has proven insuicient without condition (ii). Scenario three, computational breakthrough: a method- ological advance in computational linguistics capable of inferring language-family ailiation purely from internal distributional structure, without external bilingual or proper-name ev- idence, would constitute a genuinely novel fourth path with no precedent in the history of decipherment to date, and current evidence (Chapter 14) suggests this capability does not yet exist and may face the fundamental information-theoretic limitation discussed in the same chapter. **Finding OQ.1: The Honest** Probabilistic Assessment. None of the three scenarios of Definition OQ.3 can be assigned a high probability of occurring within any specific near-term timeframe on the basis of current evidence and trends, and this synthesis declines to offer a numerical probability estimate for full decipherment, consistent with its general methodolog- ical commitment against false precision. What can be said with somewhat more confidence is an asymmetry between the scenarios: scenario one (a bilingual find) would be suicient by itself to break the impasse essentially immediately upon confirmation, while scenarios two and three are more likely to produce incremental rather than decisive progress, extending the kind of structural, non-phonological

decipherment computational methods have already achieved (Part IV) rather than delivering the qualitative breakthrough to readable language. Readers seeking a single takeaway from this volume's treatment of the Indus script should take this

asymmetry, rather than any specific timeline, as the operative finding.

What decipherment of the Indus script would actually require, and what it would and would not reveal, deserve careful treatment. The minimum requirements for decipherment include a sound understanding of the writing system's type (logographic, syllabic, alphabetic, or mixed), a known or reconstructable target language, and either bilingual texts or sufficient text length to permit statistical decipherment. The Indus corpus satisfies none of these conditions unambiguously. The writing system's type is debated; the target language is unknown; no bilingual text has been identified; and the average inscription length of approximately five signs is too short to support the statistical analysis that allowed the decipherment of Linear B, which had longer formulaic administrative texts. This does not mean decipherment is impossible — the history of script decipherment includes transformative breakthroughs from seemingly inadequate evidence — but any claimed decipherment must be evaluated against strict criteria of internal consistency, predictive power, and convergence with independent evidence. The criteria for evaluating decipherment claims have been articulated by Sproat and Daniels, and by these criteria, no currently proposed decipherment has achieved consensus acceptance. Were a genuine decipherment to be achieved, it would not automatically resolve all interpretive questions: a deciphered text of five signs might yield a personal name, a commodity designation, or a formula whose full meaning depends on context that the seal format does not provide. The most that decipherment could directly reveal is the phonological structure of the IVC language and whatever syntactic and lexical information the inscriptions encode.

Chapter 108

Open Question: The Non-Script Symbol Systems

108.1 Graiti, Potmarks, and the Boundary of "Writing"

Definition OQ.4: The Pre-Firing Graiti Corpus Distinct from the formal seal-inscription corpus discussed in Chapter 25, a large body of single-sign or short multi-sign marks incised on pottery before firing — conventionally termed potmarks or pre-firing graiti — has been documented at IVC sites and, signif- icantly, at a number of sites in the Persian Gulf and Mesopotamia that show otherwise minimal or no Harappan material-culture influence. Some scholars (Possehl 1996; Frenez 2018) have proposed that a subset of this graiti corpus may represent a distinct, more re- stricted notational system — potentially merchants' personal marks or trade-quantity no- tations — used alongside, rather than identical to, the formal seal script, on the grounds that the graiti sign inventory overlaps only partially with the seal sign inventory and shows a different statistical distribution of sign frequency. **Note OQ.2: Why This Distinction Matters for Decipherment Strategy. If the potmark system is indeed** partially distinct from the seal script, then statistical decipherment efforts that pool all inscribed Indus material into a single corpus (as most computational studies reviewed in Part IV implicitly do) may be conflating two different sign systems with differ- ent combinatorial rules, introducing noise that could degrade the reliability of entropy and Markov-model estimates derived from the combined corpus. This is a methodological cau- tion rather than a settled finding — the graiti/script distinction itself remains debated — but it illustrates a recurring theme of this volume: apparent uniformity in the inscribed corpus may itself be partly an artefact of how scholars have chosen to categorise the data, rather than a feature of the ancient evidence.

The non-script symbol systems of the IVC, including potters' marks, graffiti on pottery, and geometric marks on terracotta objects, represent a dimension of visual communication that the exclusive focus on the formal script corpus has tended to obscure. If these non-script symbols constituted a system of community or occupational identification independent of the formal administrative script, the IVC would have supported a more pluralistic graphic culture than is implied by the single-system model that dominates most treatments of the Indus writing question. The investigation of non-script symbol systems using the same distributional and statistical methods applied to the formal script corpus represents a research programme that could clarify the boundaries between the formal script and the broader graphic repertoire, and potentially shed light on the social organisation of visual communication in the IVC.

Chapter 109

Open Question: Gender and Labour Organisation in

Harappan Society

109.1 What the Material Evidence Can and Cannot Establish

Definition OQ.5: The Evidentiary Basis for Gendered Labour Inference. Direct evidence bearing on the gendered division of labour in Harappan society is sparse and indirect, drawn primarily from three lines of evidence: (a) figurine iconography, in which female figures (the so-called "mother goddess" type discussed further in Chapter 54) substantially outnumber identifiably male figures in the terracotta corpus, though the interpretive significance of this ratio for actual social organisation, as opposed to ritual or symbolic representation, is contested; (b) skeletal evidence from the limited number of analysed burial populations, where some studies (Lukacs 1992; Robbins Schug 2011) report sex-differentiated patterns of skeletal stress and activity markers consistent with task specialisation, though sample sizes at most sites remain small enough to caution against generalisation; (c) ethnoarchaeological analogy to historically documented craft production in the same region, where certain crafts (bead-drilling, certain textile production stages) are predominantly performed by women in recent and contemporary South Asian artisan communities, though projecting this pattern onto the Harappan past without direct corroborating evidence risks the presentist fallacy. **Proposition OQ.2: A Recommendation of Interpretive Restraint. Given the thinness of the direct** evidentiary base, the analysis here recommends that claims about Harappan gender roles be held to the same Tier 1/2/3 calibration discussed in **Definition 0.1: skeletal stress-marker evidence (where**

adequately sampled) is the closest the record comes to a Tier- 1-type direct observation, figurine-ratio evidence is at best Tier 2 (interpretively mediated and contested), and any broader claim about Harappan gender ideology projected onto contem- porary social or political debates would constitute a Tier 3 claim unsupported by the present evidentiary base, regardless of which contemporary position it is invoked to support.

The question of gender organisation in the IVC has attracted renewed attention in the context of the broader shift toward social archaeology and the archaeology of everyday life that has characterised the discipline since the 1990s. Feminist archaeologists have pointed out that the emphasis on administrative seals, standardised weights, and trade networks in IVC archaeology has privileged the study of activities — commercial exchange, administrative recording, long-distance trade — that are stereotypically associated with male social roles, while giving less systematic attention to the domestic contexts in which spinning, food processing, and child-rearing took place. A reorientation of IVC archaeological priorities toward

the domestic sphere, including systematic study of residential architecture, hearth distributions, food residue analysis, and the spatial patterning of small finds within domestic contexts, would likely reveal dimensions of IVC social organisation that are currently invisible in the predominantly administrative and commercial archaeology of the civilisation.

Chapter 110

Open Question: The IVC in Comparative Civilisational

Typology

110.1 Beyond the Bronze Age Triad

Definition OQ.6: Where the IVC Sits Among Early Complex Societies. The comparative analysis of Part VIII situated the IVC primarily against its three best-known Bronze Age contemporaries (Egypt, Mesopotamia, and, more loosely, early China). A broader comparative typology — incorporating other early complex societies with weak or contested evidence for centralised monarchy, such as the Chaco Canyon and Cahokia complexes of pre-Columbian North America, the early Maya lowland polities, and the Cucuteni-Trypillia mega-sites of the Pontic-Ukrainian steppe zone discussed in the companion wheel-technology monograph — situates the IVC within a recognised cross-cultural category of "low-visibility" or "heterarchical" complex societies whose governance structures resist straightforward classification using state-formation models developed primarily from the Mesopotamian and Egyptian template. This comparative repositioning does not resolve the state-versus-heterarchy ques- tion of Chapter 86, but it reframes the IVC's apparent anomalousness: rather than being a uniquely puzzling exception to a general Bronze Age pattern of centralised monarchy, the IVC may instead be one well-documented instance of a recurring, cross-culturally attested alternative developmental pathway toward urban complexity. Case Study OQ.1: Cucuteni-Trypillia Mega-Sites as a Structural Parallel. The Cucuteni- Trypillia culture's mega-sites (such as Talianki, exceeding 300 hectares), broadly contempo- rary with the IVC's Early Harappan formative phase, present settlements of comparable or greater areal extent to Mesopotamian contemporary cities but with similarly minimal evi- dence for centralised monumental architecture, royal burial, or administrative writing — and with a poorly understood but apparently deliberate pattern of periodic, possibly ritualised, total settlement burning that has no clear IVC parallel. The comparison is instructive precisely because it is imperfect: it shows that large-scale, materially sophisticated Bronze Age societies organised on non-monarchical lines were not restricted to the IVC alone, while the points of difference (the burning pattern, the absence of an IVC-style standardised script and weight system in the Trypillia case) caution against treating "heterarchy" as a single uniform social type rather than a family of structurally related but locally distinct organisational solutions.

The comparative civilisational typology of the IVC has been complicated by the development of more nuanced frameworks for understanding political complexity in Bronze Age societies. The simple dichotomy between state and non-state polities has given way to a spectrum of organisational forms in which the IVC occupies a distinctive position — more in-

tegrated and geographically extensive than most chiefdoms, but differently organised from the temple-palace states of Mesopotamia and Egypt. The elaboration of the heterarchical model, the corporate polity concept, and the network economy framework have provided more precise analytical vocabulary for characterising this position, though the application of these frameworks to the IVC requires caution about the gap between the theoretical constructs, developed primarily from European and Mesoamerican evidence, and the specific archaeological record of the South Asian Bronze Age.

Chapter 111

Open Question: Methodological Lessons for Future

Archaeogenetic and Computational Practice

111.1 What This Volume's Four Engines Suggest About Best Practice Going Forward

Definition OQ.7: A Checklist Derived from the Volume's Recurring Failure Modes Reviewing the specific evidentiary failure modes documented across Parts I through IV — the single-genome overgeneralisation of Chapter 2, the press-conference-versus- publication conflation of Chapter 3, the corpus-size-without-bilingual-anchor failure of the Proto-Elamite comparison (Note

CC.1), and the entropy-without-semantics limita- tion of the 2024–2025 neural decipherment wave (Chapter 14) — yields a portable check- list for evaluating future claims in this and structurally similar fields: (i) does the claim rest on a sample size adequate to the population-level inference being drawn, or on a small number of exceptional finds generalised upward; (ii) is the claim's confidence level calibrated to its evidence tier (Definition 0.1), and has that calibration been preserved from the original technical publication through any subsequent popularisation; (iii) where a quantitative method is involved, has the method been validated against cases of known ground truth (the Proto-Elamite and Linear A comparisons functioning as informal con- trol cases throughout this volume), or is its output being interpreted without such a vali- dation benchmark; (iv) does the claim require, but lack, an external anchor of the specific kind that has historically been necessary for similar inferential tasks (a bilingual text, an outgroup population, a labelled training corpus); and (v) is the claim's interpretive con- tent separable from any contemporary identity-political stake that might bias its reception, and if not, has that stake been made explicit rather than left implicit. **Finding OQ.2: A Closing Methodological Recommendation. This checklist is not spe- cific to the IVC** and is offered, in the spirit of Note 19.1's invitation to future scholarship, as a general-purpose evaluative tool for any historical or prehistoric research domain charac- terised by fragmentary direct evidence, active interdisciplinary method development, and significant contemporary political stakes in particular conclusions — a combination of condi- tions that, while unusually acute in the Indus case, is by no means unique to it, and which this volume's structural diagnosis (Chapter 17) is intended to generalise beyond the IVC case study that occasioned it.

The methodological lessons of IVC research for future archaeological practice extend across multiple dimensions. The recovery bias introduced by the exclusive focus on fired brick ur-

ban centres in the early history of the field has been substantially corrected by systematic surface survey, but the under-investigation of rural settlement contexts means that understanding of the non-urban majority of the IVC population remains rudimentary. The integration of palaeoenvironmental reconstruction with site-specific excavation data has transformed understanding of the ecological context of IVC urbanism and decline, and represents a methodological standard that should be applied more systematically. The application of ancient DNA analysis has demonstrated that long-standing debates about population continuity and migration can be addressed through genomic data with appropriate methodological safeguards, though the interpretive relationship between genetic ancestry and cultural identity requires continued critical attention. Isotope analysis of human and faunal remains has begun to illuminate patterns of mobility and dietary access that are otherwise archaeologically invisible. The outstanding challenge is the integration of these multiple data streams within interpretive frameworks that do not privilege any single line of evidence but use each to constrain the interpretation of the others. The IVC case also illustrates the importance of publishing data openly and completely: much of the interpretive controversy that has attended the field over the past century could have been resolved more quickly if the full corpus of inscriptions, faunal assemblages, and stratigraphic data had been available to the scholarly community rather than remaining in the possession of individual excavators or national archaeological services whose publication timelines extended over decades.

Chapter 112

Open Question: A Research Agenda for the Next Decade

112.1 Prioritising Future Investment Across the Four Engines

Definition OQ.8: A Ranked Set of High-Value Future Investigations. Drawing together the specific evidentiary gaps identified throughout this study, the following investments would, in the authors' assessment, yield the highest expected evidentiary return per unit of likely research cost: (i) additional ancient-DNA sampling from core IVC urban sites beyond the single Rakhigarhi individual, particularly targeting Mohenjo-daro and Harappa burial contexts where preservation conditions permit, to directly address the single-genome limitation of Chapter 2; (ii) systematic, well-funded excavation of at least one major unexcavated site of the Ganweriwala scale (Chapter 63), to test whether corpus expansion at this scale meaningfully changes the statistical picture available to computational decipherment efforts; (iii) continued high-resolution palaeoclimate proxy development (additional speleothem and lake-sediment records) in the specific Ghaggar-Hakra catchment area, to narrow the dating un- certainty on the 4.2 ka event's specific regional manifestation beyond the current speleothem evidence reviewed in Appendix B; and (iv) continued, methodologically cautious applica- tion of large-language-model and other computational techniques to the existing inscribed corpus, not with the expectation of full decipherment absent a bilingual anchor, but with the more modest and achievable goal of further refining the structural (non-semantic) character- isation of the script's combinatorial properties begun in Part IV. **Finding OQ.3: A Final Word on Expectation** Management. None of the four priority investments of Definition OQ.8 is likely, even if fully funded and successfully executed, to resolve the IVC's central contested questions — language ailiation, ethnic and cultural con- tinuity, governance structure — with the kind of finality this volume's readers might prefer. Each would, however, meaningfully narrow the relevant uncertainty intervals and improve the evidentiary base's robustness, which is the realistic and achievable standard of progress

this volume recommends researchers, funders, and the interested public alike adopt for a field whose central puzzle has, after a century of sustained investigation, proven genuinely diicult rather than merely under-resourced. The Indus Enigma will very likely remain, in its core respects, an enigma for some time yet; the present account's hope is to have left that enigma better characterised, more precisely bounded, and more honestly described than it found it.

A responsible research agenda for IVC studies in the coming decade must address several priority needs. Systematic excavation of Ganweriwala, the largest unexcavated major IVC site, represents the single most significant gap in the comparative study of IVC urbanism and should be a priority for collaborative Pakistani and international archaeological effort.

Expanded ancient DNA sampling from IVC-period contexts — including sites not sampled by the Rakhigarhi project, and from multiple phases of occupation at well-stratified sites like Harappa — would allow the internal genomic diversity of the IVC population to be characterised rather than inferred from a single individual. The application of high-resolution palaeoclimate proxies from South Asian contexts is needed to sharpen the chronological alignment between climate events and settlement pattern changes. Complete and open-access publication of the full corpus of IVC inscriptions, with standardised sign inventories and contextual data, would enable more rigorous statistical analysis than is currently possible. Integration of community participation into IVC research, both to improve site protection and to ensure that communities living near major sites have a stake in their investigation and presentation, represents an ethical imperative that is also a practical research asset. Finally, the development of institutional frameworks for scientific collaboration between Indian and Pakistani archaeological programmes, largely absent since partition, would bring the full site corpus under coordinated research attention for the first time and represents the single most transformative change that the political willingness of both governments could produce for the future of IVC scholarship.

Chapter 113

Closing Synthesis: The Indus Valley Civilisation as a Case

Study in Bounded Knowledge

113.1 What a Century of Research Has and Has Not Settled

Note OQ.3: A Final Inventory. A century of sustained archaeological, and more recently genomic and computational, investigation has firmly established the IVC as one of the great Bronze Age urban civilisations: a territorially vast, materially sophisticated, internally standardised society spanning the modern India-Pakistan border region from roughly 3300 to 1300 BCE, with sophisticated urban planning, craft specialisation, long-distance trade, and a still-undeciphered writing system. What remains genuinely unresolved — not merely underpopularised but actually unresolved at the level of the specialist literature itself — is the script's language ailiation, the precise nature of Harappan governance, and the degree and character of cultural and linguistic continuity between the Harappan population and later South Asian populations. This volume has attempted to keep these two categories — the well-established and the genuinely open — clearly distinct throughout, in the conviction that a calibrated account of partial knowledge is of more lasting scholarly and public value than a confident account that outruns its evidence in either direction. **Definition OQ.9: The Volume's Central** Methodological Contribution. If this volume has a single methodological contribution beyond its synthesis of the substantive IVC evi- dence, it is the explicit tier framework of Definition 0.1 and its consistent application across four otherwise quite distinct evidentiary domains — ancient genomics, historical and com- putational linguistics, archaeological material culture, and the sociology of public science communication discussed in Part XVI. The recurring finding, replicated across all four domains, is that the gap between specialist-literature confidence and public-discourse confi- dence is itself a measurable and explicable phenomenon, driven by identifiable structural pressures (press-release incentives, textbook compression, platform amplification, heritage- tourism economics) rather than by any single actor's misconduct, and that closing this gap requires attention to the communication pipeline as much as to the underlying research itself.

The Indus Valley Civilisation as a case study in civilisational complexity without state power has implications that extend into the present, as archaeologists and historians continue to grapple with the question of how complex societies are organised and what kinds of institutions are necessary for the maintenance of large-scale social order. The IVC demonstrates that cities, long-distance trade, craft specialisation, and shared cultural norms can coexist without the institutional infrastructure typically associated with state formation, at least for a period of several centuries. Whether this demonstrates that states are unnecessary for civilisational

complexity, or simply that the IVC had not yet developed the institutional innovations that would eventually produce state-level organisation, is a question that the evidence does not definitively resolve — and that may ultimately be unanswerable from archaeological data alone.

Chapter 114

Open Question: Children, Play, and Everyday Life

114.1 Toys, Games, and the Texture of Daily Experience

Definition OQ.10: Beyond the Administrative and Monumental Record Much of this volume's evidentiary discussion, by necessity, centres on the categories of evidence best suited to addressing its central contested questions: script, governance, trade, and continuity. A smaller but evocative body of evidence speaks more directly to the texture of Harappan everyday and domestic life, including the terracotta cart models already discussed (Definition WHL.1) in their toy capacity, small terracotta animal fig- urines with movable parts (some apparently designed as pull-toys), gaming pieces and dice (cubical, with pip-marked faces in patterns suggesting board or dice games of a type whose specific rules cannot be reconstructed from the pieces alone), and whistles and rattles. This evidence base, while incapable of resolving the volume's central debates, is a useful corrective against

an overly administrative or monumentalist reading of Harappan society, reminding readers that the same urban population whose standardised weights and seals occupy much of this synthesis's analytical attention also raised children, played games, and pursued the ordinary textures of domestic life materially attested, however incompletely, in this smaller and less analytically prominent body of evidence. **Note OQ.4: A Closing Reflection. This volume closes, accordingly, not with a final res- olution of the** Indus Valley Civilisation's great unresolved questions, but with a reminder that the civilisation under study was, before it was a research problem, a lived human society of millions of people across more than a millennium, whose descendants' modern genomic, linguistic, and cultural identities remain, as this volume has shown, a still-contested but gen- uinely fascinating subject of ongoing inquiry.

The study of childhood in the IVC is constrained not only by preservation issues but by the analytical frameworks that archaeologists bring to the evidence. The category of childhood is culturally variable — the age ranges, the social roles, and the material markers of childhood differ substantially across societies — and projecting modern Western assumptions about childhood onto the IVC material record risks producing anachronistic interpretations. Comparative evidence from other Bronze Age societies suggests that children in urban contexts participated in craft production from an early age and that the boundary between play and work was considerably more permeable than in modern industrial societies. The interpretation of miniature pottery and animal figurines as toys rather than as craft training tools or ritual objects may reflect an assumption about the nature of childhood that is not independently supported by the IVC evidence.

Chapter 115

Open Question: Standardisation Mechanisms Without a

Visible State

115.1 How Was Uniformity Actually Achieved?

The brick ratios, weight series, seal iconography, and ceramic forms documented across this volume are remarkably uniform across a territory exceeding a million square kilometres, yet the evidence for the kind of centralised bureaucratic apparatus that would conventionally explain such uniformity in other Bronze Age contexts is, as Chapter 86 discusses, weak. Three broad mechanisms, not mutually exclusive, have been proposed in the literature to explain standardisation without strong central enforcement: a shared craft-guild or apprenticeship tradition transmitting technical norms informally across generations and regions; market-driven convergence, in which traders and buyers across the IVC's interaction sphere simply preferred goods conforming to recognised standards, creating an economic selection pressure toward uniformity without requiring any administrative mandate; and a shared ideological or religious framework, possibly connected to the iconographic and ritual evidence of Part X, in which conformity to material standards carried symbolic as well as practical significance. None of these three mechanisms can currently be confirmed or ruled out on the available evidence, and they are not mutually exclusive: a plausible reconstruction might combine elements of all three, with craft-guild transmission establishing the initial standards, market pressure reinforcing and propagating them across the trade network, and a shared symbolic framework lending them additional social weight beyond pure economic convenience. This question remains, like much of the governance debate it adjoins, a genuinely open one, and is flagged here as a priority area for future research combining archaeological, economic- modelling, and comparative-anthropological approaches.

The standardisation problem in IVC studies connects to a broader theoretical debate about the relationship between norms and institutions. Social norms can achieve a high degree of standardisation without formal institutional enforcement, particularly in contexts where the cost of deviation from the norm — in terms of reputational damage, loss of trading partners, or exclusion from shared facilities — is high enough to make compliance individually rational. The IVC's standardisation of weights and measures may represent exactly this kind of norm-based standardisation maintained by the self-interest of participants in the exchange network, rather than by any external enforcement mechanism. The challenge for archaeological analysis is to develop methods for distinguishing between norm-based and institution-enforced standardisation — a distinction that may be detectable in the patterns of local variation and temporal change in the standardised systems if sufficient fine-grained data are available.

Chapter 116

Open Question: The Possibility of Multiple Indus Scripts

116.1 Is the ”Indus Script” a Single System or a Family of Related Notations?

The convention of treating all inscribed Indus material as a single unified script rests partly on the observation that seal inscriptions, copper-plate inscriptions, and pottery graiti share a substantially overlapping sign repertoire, but the potmark distinction discussed in Chapter 89 raises a more general possibility that has received comparatively little systematic attention: that what is conventionally lumped together as “the Indus script” may in fact be better understood as a family of related but functionally and perhaps structurally distinct notational subsystems, used in different contexts (formal sealing, informal marking, possibly numeral or quantity notation) by overlapping but not identical communities of practice. If this possibility were borne out by future systematic study, it would have

direct implications for the computational decipherment efforts surveyed in Part IV, since those efforts have generally treated the inscribed corpus as a single homogeneous system for statistical purposes, and a multi-system reality would mean that some portion of the apparent statistical regularity, or irregularity, detected in such studies might reflect an artefact of inappropriately pooling dis- tinct systems rather than a genuine structural property of any single underlying script. This remains, for now, a speculative possibility rather than an established finding, and is flagged here as a candidate direction for future systematic corpus reclassification work.

The question of script multiplicity in the IVC has a direct parallel in the history of writing systems generally: many early writing traditions show internal diversity that subsequent standardisation or scholarly convention has retrospectively unified into a single system. The Linear B script, which appears relatively uniform to modern eyes, shows regional and scribal variation that is detectable through careful sign-by-sign analysis; Mesopotamian cuneiform encompasses multiple distinct writing traditions that are sometimes treated as a single system for comparative purposes. The IVC script, whose internal diversity has been a topic of debate since the earliest systematic studies of the corpus, may represent a case where the diversity is greater than in these parallels but where the scholarly convention of treating it as a single system has obscured this diversity. Resolution of the script unity question has practical implications for decipherment attempts: if the corpus is internally diverse, attempts to develop a single phonological key applicable to all inscriptions may be misguided from the start.

Chapter 117

Museums, Heritage Sites, and the Public Presentation of the

IVC

117.1 The National Museum Frameworks

Definition REC.1: Three National Museum Traditions. The IVC's heritage and findings are presented to the public principally through three national museum traditions, each reflecting a distinct institutional history and, to varying degrees, a distinct national narrative emphasis: the National Museum, New Delhi, and the site museums at Lothal, Dholavira, and Rakhigarhi in India; the National Museum of Pakistan, Karachi, and the on-site museums at Mohenjo-daro and Harappa; and smaller diaspora and university museum collections (the Penn Museum's Harappa collection, assembled during early twentieth-century excavations under colonial-period archaeological administration, being among the most significant outside South Asia). The post-1947 partition of the subcontinent divided the IVC's two largest excavated cities — Mohenjo-daro to Pakistan, Harappa also to Pakistan, with most subsequently excavated major sites (Dholavira, Rakhigarhi, Lothal, Kalibangan) falling within India — a division with no relationship to the ancient civilisation's own internal organisation but with significant consequences for how each successor state's heritage institutions have framed their own relationship to the IVC. **Finding REC.1: Divergent Framing Without Divergent Evidence.** Comparative content analysis of museum interpretive panels and accompanying educational material at major IVC sites in both countries (Coningham & Young 2015) finds that the underlying archaeological evidence presented is broadly similar — the same chronology, the same major findings, sub- stantially the same artefact types — while the framing narrative accompanying that evidence differs more substantially, with Pakistani institutional framing more often emphasising the IVC as part of a broader regional pre-Islamic heritage continuous with the territory of the modern state, and some Indian institutional and popular framing more often emphasising direct cultural and religious continuity with later Vedic and Hindu tradition. Since this vol- ume's Chapters 6 through 8 and Chapters 7 establish that the evidentiary basis for either strong continuity claim is, at the linguistic and genetic Tier-2 level, considerably weaker than either national framing typically conveys to a lay museum visitor, the museum case is a use- ful illustration of how Tier 3 identity narratives can become embedded in ostensibly neutral heritage-presentation infrastructure without explicit scientific misstatement at the level of in- dividual artefact labels.

117.2 UNESCO World Heritage Status and Site Conservation

Case Study REC.1: Mohenjo-daro's Conservation Crisis. Mohenjo-daro, inscribed as a UNESCO World Heritage Site in 1980, has faced a persistent and well-documented conservation crisis driven by

rising subsurface salinity and water-table fluctuation, which causes salt ef- florescence and consequent disintegration of the site's exposed fired-brick structures — the same brick fabric whose standardisation is discussed in Definition T.1. UNESCO and Pak- istani heritage authorities have implemented mitigation measures (subsurface drainage, con- trolled groundwater pumping, brick consolidation treatments) with partial but incomplete success, and the site's long-term physical conservation remains, independently of any schol- arly debate about its interpretation, a live practical concern: a substantial fraction of the exca- vated structures visible in early twentieth-century photographs have measurably deteriorated in the intervening century, a reminder that the evidentiary base the analysis here relies upon is not static but is itself subject to ongoing loss.

The public presentation of the IVC at museums and heritage sites reflects and shapes the interpretive frameworks within which diverse audiences understand the civilisation. The National Museum in New Delhi, the National Museum of Pakistan in Karachi, and the site museums at Harappa and Mohenjo-daro present the IVC from different national perspectives that inevitably colour the interpretive frameworks offered to visitors. The tension between archaeological accuracy and national heritage narratives is particularly acute for the IVC, whose significance as a pre-Aryan and pre-Islamic civilisation makes it a contested site of national memory in both India and Pakistan. The development of interpretive frameworks that acknowledge the civilisation's ambiguous legacy — its relationship to the historical cultures of both countries is real but indirect — while avoiding the nationalist over-identification that distorts its archaeological record represents one of the more delicate challenges in the public presentation of South Asian prehistory.

Chapter 118

The IVC in School Curricula and Popular Textbooks

118.1 Curriculum Content Analysis

Definition REC.2: The Textbook Simplification Problem. Secondary-school history curricula in both India and Pakistan, and in international contexts where South Asian history is taught, necessarily compress the IVC's contested evidentiary picture into brief textbook treatments, typically a few pages, that cannot accommodate the tier-distinctions and evidentiary caveats this volume has argued are essential to responsible treatment of the material. Comparative textbook analysis (Sankalia 1974 for the formative period; more recent state-level curriculum reviews in both countries) documents a recurring pattern in which textbook authors, working under length constraints, resolve genuinely unresolved questions (script language ailiation, the Aryan migration question, urban governance structure) into confident single-sentence assertions that do not reflect the field's actual evidentiary state, with the specific direction of oversimplification varying by jurisdiction and period in ways that track, more often than not, the same Tier 3 identity-political pressures discussed in Definition 0.1 and

The curriculum challenge for the IVC is compounded by the rapid pace of change in the specialist literature. The ancient DNA revolution, which has substantially reshaped understanding of South Asian population history since 2015, has produced findings that are not yet incorporated into most secondary school textbooks in India or Pakistan. Students who learn about the IVC from textbooks written before 2019 are learning a version of the civilisation's history that predates the Rakhigarhi genome and the Narasimhan et al. study — two contributions that have significantly clarified the relationship between IVC populations and later South Asian communities. The update cycle for secondary school textbooks is typically longer than the pace of major discoveries in a fast-moving field, creating an inherent lag between specialist knowledge and public curriculum that is particularly consequential for politically sensitive topics where the most recent findings carry the most significant implications for inherited narratives.

Chapter 119

Proposition REC.1: A Pedagogical Recommendation. Given the textbook-compression

problem documented in Definition REC.2, this volume's tier framework (Definition 0.1) is offered as a candidate pedagogical tool precisely because it is compact enough for textbook-length treatment while preserving the essential calibration distinction: a textbook sentence of the form "the IVC's language and the ethnic identity of its population remain genuinely debated among specialists, while its urban achievements are well established" requires barely more space than the confident single-narrative alternative, while avoiding the specific over-claiming pattern this Part has documented in both national contexts.

Chapter 120

Journalism, Documentary Media, and the Public Science

Communication Gap

120.1 The Press-Release-to-Headline Pipeline Revisited

Definition REC.3: A General Model of Science-to-Headline Distortion The specific 2018–2019 Rakhigarhi press-conference episode analysed in detail in Chapter 3 is, this Part argues, an instance of a general pipeline failure mode documented across science journalism studies more broadly (Sumner et al. 2014, in a biomedical con- text, finding systematic exaggeration accumulating at each stage from journal article to press release to news headline): a nuanced, hedged technical finding is first summarised by the researchers' own institutional press oice in a more confident register than the un- derlying publication supports, then further compressed by news desks operating under headline-length and attention-economy constraints, with each successive stage of

com- pression preferentially discarding hedges, sample-size caveats, and confidence intervals because these reduce a headline's apparent newsworthiness and conciseness. The Rakhigarhi case is unusual chiefly in the public stakes attached to its specific subject matter, not in the underlying distortion mechanism, which is a structural feature of contempo- rary science communication. **Case Study REC.2: Documentary Television Treatment of the IVC. Documentary televi- sion and** streaming-platform treatments of the IVC (a genre including several major produc- tions across Indian, Pakistani, British, and American broadcasters between 2000 and 2024) face a structural pressure toward narrative resolution that is in tension with the analysis here's central finding of genuine, currently irreducible uncertainty: a documentary that concludes by telling its audience that the central questions remain unresolved is, in commissioning- editor terms, generally judged less satisfying than one that delivers a confident answer, cre- ating a systematic commissioning and editing bias toward documentaries that overstate con- fidence in one or another resolution of the script, language, or continuity questions, largely independent of which specific resolution is favoured by the production's country of origin or production team.

The role of social media in shaping public understanding of IVC topics has accelerated the fragmentation of the information environment in ways that create both opportunities and risks for science communication. On one hand, researchers can communicate findings directly to interested audiences without the mediation of journalists who may lack the specialist knowledge to contextualise complex genomic or archaeological findings. On the other hand, social media platforms' algorithmic amplification of emotionally resonant content tends to favour the most dramatic and politically charged interpretations of IVC findings, and the

absence of editorial gatekeeping means that OIT proponents and other minority scholarly positions can achieve a visibility on social platforms that significantly exceeds their standing in the peer-reviewed literature. The development of effective strategies for communicating nuanced, probabilistic scientific findings about South Asian prehistory to social media audiences remains an unresolved challenge for the field.

Chapter 121

Diaspora Discourse and Online Public Debate

121.1 The Internet-Era Amplification of Tier 3 Claims

Definition REC.4: Social Media as an Amplifier of Identity-Political Claims. Online discourse about the IVC — across social media platforms, diaspora community forums, and politically aligned media outlets — impressionistically exhibits a markedly higher proportion of confident Tier 3 identity claims relative to the proportion found in the underlying technical literature, though this volume is not aware of a published systematic content-analysis study quantifying this impression specifically for IVC-related discourse, and the observation should accordingly be read as a plausible extension of the general pattern documented for other contested-science domains by which platforms with engagement-optimised algorithmic curation tend to amplify confident, emotionally resonant claims over hedged, uncertainty-acknowledging ones, rather than as an IVC-specific finding with its own dedicated empirical citation. This amplification dynamic operates independently of, and in addition to, the press-pipeline distortion of Definition REC.3, and the two interact: a press-pipeline-distorted headline claim is itself further amplified and stripped of remaining nuance as it propagates through social media resharing. **Note REC.1: A Closing Observation on the Information Environment. The** cumulative effect of the museum-framing pattern of Finding REC.1, the textbook-compression pattern of Definition REC.2, the press-pipeline distortion of Definition REC.3, and the social-media amplification dynamic of Definition REC.4 is an information environment in which a lay per- son encountering IVC-related content through any of these ordinary channels is consider- ably more likely to encounter confident, tier-conflated claims than the calibrated, uncertainty- preserving characterisation this volume has argued the evidence actually supports. This is not a claim about any single actor's bad faith — each stage in this pipeline operates under its own legitimate institutional pressures (conservation funding narratives, curriculum length limits, headline economics, platform engagement incentives) — but it is a structural expla- nation for why public understanding of the IVC's contested questions so often diverges from the specialist consensus on what is and is not currently known, and it is offered here as the final piece of the present account's broader argument that the Indus Valley Civilisation is as instructive a case study in the sociology of contested knowledge production as it is a fascinat- ing subject in its own archaeological right.

Diaspora South Asian communities, particularly in the United Kingdom, North America, and Australia, have developed distinctive engagements with IVC heritage reflecting the political formations of South Asian identity in diaspora contexts. Hindu nationalist organisations operating in the diaspora have been significant consumers and distributors of OIT literature, funding conferences and online platforms that amplify the minority scholarly po-

sition in ways that exceed its evidential support. The digital acceleration of this dissemination — through YouTube channels, WhatsApp networks, and diaspora news platforms — has created information environments in which OIT claims circulate widely among educated South Asian diaspora communities without the contextualisation that specialist knowledge would provide. Pakistani diaspora engagements with the IVC tend to foreground the civilisation's location within Pakistani territory and its significance as evidence of the antiquity of the cultural landscape that preceded both Aryan and Islamic civilisations in the region. Tamil diaspora communities have shown particular interest in the Dravidian substrate hypothesis, consistent with the political history of Tamil linguistic nationalism. The diversity of diaspora engagements with IVC heritage reflects the civilisation's unusual position as a site of overlapping national, ethnic, linguistic, and religious identity investments that no single interpretive framework can simultaneously satisfy. The scholarly task of engaging with these diverse public constituencies without either dismissing their interest or accommodating their interpretive investments represents one of the more delicate challenges facing the field's communication with its non-specialist audiences.

Chapter 122

Academic Conference Discourse and the Politics of Citation

122.1 Conference Venues as a Site of Tier 3 Contestation

Definition REC.5: The Conference Circuit Pattern. Academic conferences specifically convened around IVC themes — a circuit including the World Archaeological Congress sessions, the biennial Harappan Studies meetings, and a growing number of genetics-archaeology joint symposia following the 2018–2019 ancient-DNA wave — have, according to participant accounts and published proceedings analysis (Possehl 2002 for the earlier period; subsequent informal accounts in the wake of the Rakhigarhi episode), increasingly become venues where the Tier 3 political stakes discussed in Definition 0.1 surface explicitly in ways that the peer-reviewed literature itself, bound by more formal evidentiary conventions, more often suppresses or hedges. This is not unique to IVC studies — comparable dynamics have been documented in other politically charged archaeological subfields, including Classical Mediterranean and Holy Land archaeology — but it means that the conference-discourse layer of the field constitutes a distinct evidentiary register from the published-literature layer, one in which scholars sometimes express, in question-and-answer sessions or informal discussion, confidence levels their own published work does not support. **Note REC.2: A** Caution About Citation as a Tier 3 Signal. Citation patterns in IVC stud- ies — which authors cite which other authors' work approvingly or critically — have them- selves, in a small but growing body of bibliometric self-study within the field, begun to show clustering along lines that track national and political ailiation as much as methodological school, a pattern familiar from bibliometric studies of other politically contested fields. This volume has attempted, throughout, to cite primary technical sources (Narasimhan et al., Rao et al., Witzel, Parpola, and others) on the basis of methodological relevance rather than any attempt to balance citation counts across national or political lines, but readers conducting their own further reading are cautioned that citation network position in this field is not al- ways a reliable proxy for technical rigour, and should be evaluated source by source against the Tier framework of Definition 0.1 rather than against the citing author's institutional or national ailiation.

Academic conference discourse on the IVC, particularly in the post-genomics era, has been shaped by the intersection of genuine scientific uncertainty with the political implications of interpretive positions. The reception of Narasimhan et al. (2019) at conferences in South Asia illustrated the degree to which findings about ancient population movements can produce responses structured more by political alignment than by scientific evaluation: panellists from nationalist scholarly networks focused on technical objections to sampling and modelling assumptions deployed in ways suggesting motivated reasoning. The politics of citation — which scholars are cited, in which journals, and by which international collabo-

rators — shapes the construction of specialist authority in ways not always transparent to outside observers. The exclusion of certain South Asian scholars from international collaborative projects, and the concentration of ancient DNA analysis capacity in a small number of well-funded Western and Chinese laboratories, has created structural asymmetries in the production of knowledge about South Asian prehistory. The development of ancient DNA capacity within South Asian institutions — a process that has accelerated since 2019 — promises to diversify the geographic locus of knowledge production, though the political pressures on South Asian-based researchers working on questions that intersect with nationalist identity claims are not automatically reduced by institutional location. The long-term health of IVC studies depends on the development of a genuinely global and open scholarly community in which the constraints imposed by both Western institutional dominance and nationalist political pressure are progressively weakened by the increasing geographic diversity of researchers and the open publication of primary data.

Chapter 123

Tourism, Cultural Heritage Economics, and Site Access

123.1 Visitor Numbers and Economic Stakes in Site Presentation

Definition REC.6: Heritage Tourism as an Institutional Stakeholder Beyond the scholarly and educational stakes discussed elsewhere in this Part, IVC sites are also significant heritage-tourism assets for their host regional and national economies — Mohenjo-daro and Dholavira each attract substantial domestic and, to a lesser extent, international visitor traic, with associated local economic activity (guiding, hospitality, retail) creating a distinct institutional stakeholder interest, separate from any specifically nationalist or religious motivation, in presenting site narratives that are accessible, en- gaging, and confident rather than hedged and uncertain. This tourism-economics pres- sure operates as a further, largely independent contributor to the same general pattern of public-facing overconfidence relative to the specialist evidentiary base documented throughout this Part, and it is worth distinguishing analytically from the more frequently discussed nationalist and religious motivations, since it would persist even in a counter- factual scenario in which those other pressures were entirely absent. **Proposition REC.2: Heritage Economics and Conservation Funding as a Genuinely Positive** Convergence. Notwithstanding the interpretive overconfidence concern of Definition REC.6, heritage

tourism revenue and associated international conservation funding (includ- ing UNESCO World Heritage Fund contributions and bilateral conservation partnerships) constitute one of the few practical funding mechanisms available for the physical conserva- tion needs documented in Case Study REC.1, and in this respect the economic stakeholder interest in IVC sites, whatever its effect on interpretive framing, aligns with rather than works against the scholarly community's interest in preserving the physical evidentiary base for fu- ture research. This is offered as a deliberately balanced closing observation: not every insti- tutional pressure on IVC discourse documented in this Part operates purely to the detriment of the field's evidentiary integrity, and the tourism-conservation linkage is a clear case of a structurally beneficial alignment of interests. Appendix A Technical Notes on the Genomic Methods Referenced in Part I A.1 -Statistics and qpAdm The -statistics framework, developed by Patterson et al. (2012) and implemented in the ADMIXTOOLS software package, is the principal quantitative framework for estimating pop- ulation ancestry proportions in ancient-DNA studies. Its logic is based on allele frequency correlations across populations. **Definition A.1: -Statistics — Formal Definition. Let , , , denote populations** represented by genotype data. The 2, 3, and 4 statistics are defined as: 2(,) = [(−)2] 3(; ,) = [(−)(−)] 4(, ; ,) = [(−)(−)] where denotes the allele frequency in population at a given site, and expectations are taken over genome-wide SNPs. The 3(; ,) statistic, when significantly negative, is ev- idence that is an

admixed population with and as component sources (the treeness property). The 4(, ; ,) statistic, when significantly non-zero, indicates that the four populations are not consistent with a simple tree topology and that gene flow has occurred between branches. **Definition A.2: qpAdm —** Admixture Modelling. qpAdm (Haak et al. 2015, implemented in ADMIXTOOLS) extends the 4 framework to estimate the mixing proportions 1, … , such that a target population can be modelled as a linear combination of source popula- tions 1, … , : $\sum \sum \approx$ $=1$, ≥ 0, $=1 = 1$. The model is fitted by minimising a weighted sum of squared residuals between observed and predicted 4 statistics involving the target, sources, and a set of outgroup populations. The goodness-of-fit is assessed by a -value (fit) derived from the 2 distribution of the normalised residuals; a fit > 0.05 is the conventional threshold for a model not being re- jected. When applied to IVC-related populations in Narasimhan et al. (2019), the three-source model (Iranian-farmer-related, AASI, Central_Steppe_MLBA) is not rejected for post-2000- BCE South Asian populations, while the two-source model without Steppe is rejected for the same populations, providing the formal statistical basis for the chronologically ordered admixture sequence described in

Appendix A

Technical Notes on the Genomic Methods Referenced in Part I

A.1 f-Statistics and qpAdm

The f-statistics framework, developed by Patterson et al. (2012) and implemented in the ADMIXTOOLS software package, is the principal quantitative framework for estimating population ancestry proportions in ancient-DNA studies. Its logic is based on allele frequency correlations across populations.

Definition A.1: f-Statistics — Formal Definition. Let A, B, C, D denote populations represented by genotype data. The f_2, f_3, and f_4 statistics are defined as:

$$\begin{aligned} f_2(A, B) &= \mathbb{E}[(p_A - p_B)^2] \\ f_3(C\,;\,A, B) &= \mathbb{E}[(p_C - p_A)(p_C - p_B)] \\ f_4(A, B\,;\,C, D) &= \mathbb{E}[(p_A - p_B)(p_C - p_D)] \end{aligned}$$

where p_X denotes the allele frequency in population X at a given site, and expectations are taken over genome-wide SNPs. The $f_3(C\,;\,A, B)$ statistic, when significantly negative, is evidence that C is an admixed population with A and B as component sources (the treeness property). The $f_4(A, B\,;\,C, D)$ statistic, when significantly non-zero, indicates that the four populations are not consistent with a simple tree topology and that gene flow has occurred between branches.

Definition A.2: qpAdm — Admixture Modelling. `qpAdm` (Haak et al. 2015, implemented in ADMIXTOOLS) extends the f_4 framework to estimate the mixing proportions $\alpha_1, \ldots, \alpha_k$ such that a target population T can be modelled as a linear combination of k source populations $S_1, \ldots, S_k$:

$$p_T \approx \sum_{i=1}^{k} \alpha_i \, p_{S_i}, \quad \alpha_i \geq 0, \quad \sum_{i=1}^{k} \alpha_i = 1.$$

The model is fitted by minimising a weighted sum of squared residuals between observed and predicted f_4 statistics involving the target, sources, and a set of outgroup populations. The goodness-of-fit is assessed by a p-value (p_{fit}) derived from the χ^2 distribution of the normalised residuals; a $p_{\text{fit}} > 0.05$ is the conventional threshold for a model not being rejected. When applied to IVC-related populations in Narasimhan et al. (2019), the three-source model (Iranian-farmer-related, AASI, Central_Steppe_MLBA) is not rejected for post-2000-BCE South Asian populations, while the two-source model without Steppe is rejected for the same populations, providing the formal statistical basis for the chronologically ordered admixture sequence described in Chapter 1.

A.2 Linkage Disequilibrium Decay Dating

The timing of admixture events in ancient-DNA studies is commonly estimated from the decay of linkage disequilibrium (LD) in the admixed population's genome.

Definition A.3: LD-Decay Admixture Dating. When two populations with different allele frequency profiles admix, their genetic material in the descendant population is initially in blocks of the length present in the source population's chromosomes. Recombination, at a rate of approximately 1 centimorgan (cM) per generation, progressively shuffles these blocks into smaller and smaller segments. The expected length of ancestry-informative segments at generation g after a single pulse of admixture is approximately $1/g$ Morgans. By identifying segments of chromosomal ancestry (using local ancestry inference methods such as HAPMIX or RFMix) and fitting an exponential decay model to the length distribution of these segments, one can estimate the number of generations since admixture and, given a generation time assumption (usually 28–30 years for ancient populations), convert to calendar years. Confidence intervals for this dating method are typically $\pm$200–500 years for admixture events in the range of 100–200 generations ago, making it consistent with, but not more precise than, the calendar-year uncertainties from radiocarbon dating reviewed in Chapter 9.

Appendix B

Technical Notes on Palaeoclimate Proxies Referenced in Part III

B.1 Speleothem Oxygen Isotope Records

Definition B.1: Speleothem δ^{18}O as a Monsoon Proxy

Speleothems (cave stalagmites and stalactites) precipitate calcium carbonate ($CaCO_3$) from percolating groundwater whose isotopic composition reflects that of the rainwater from which it derives. The oxygen isotope ratio of cave calcite, expressed as δ^{18}O (the permille deviation of the $^{18}O/^{16}O$ ratio from the VSMOW standard), tracks the isotopic composition of precipitation, which in monsoon-dominated South Asian climate systems is primarily controlled by the *amount effect*: heavier monsoon rainfall preferentially depletes ^{18}O in precipitation due to Rayleigh distillation along the moisture transport path, producing more negative δ^{18}O values in high-rainfall years and less negative values in low-rainfall years. High-resolution uranium-thorium ($^{230}Th/^{238}U$) dating of speleothem layers, achievable to $\pm$10–20 years in favourable samples, provides an absolute chronology for the palaeomonsoon record that is independent of the radiocarbon calibration curve and its IVC-period plateau. The Kotla Dahar and Sahiya cave records referenced in Chapter 10 exploit this dating advantage to provide a higher-resolution absolute chronology for the 4.2 ka event in northern India than is available from most archaeological contexts.

B.2 Palaeo-Channel Remote Sensing

Definition B.2: Remote Sensing of the Ghaggar-Hakra Palaeo-Channel. The Ghaggar-Hakra river system, which drained the eastern IVC zone during the Mature Harappan period, has been substantially reduced by subsequent Holocene geomorphological change and modern water diversion. Its former extent and channel geometry have been reconstructed using: (a) Landsat and SRTM elevation data, which preserve subtle topographic signatures of former floodplain and channel fill beneath vegetation and aeolian sediment cover; (b) CORONA declassified intelligence satellite imagery from the 1960s, which provides a pre-modern-development baseline for channel trace identification; (c) archaeological site density mapping, since Mature Harappan settlements cluster along the palaeo-channel trace at a density consistent with dependence on the river for agriculture and water supply. Giosan et al. (2012) combined these data sources to argue that the Ghaggar-Hakra's primary sources were monsoon-fed tributaries rather than Himalayan glacier melt — a conclusion with direct implications for the river's sensitivity to the 4.2 ka monsoon reduction documented in speleothem records,

and for the *Saraswati* identification debate of Note 10.1.

Appendix C

Technical Notes on Bayesian Chronological Modelling

C.1 Bayesian Radiocarbon Calibration

Definition C.1: Bayesian Chronological Modelling of Stratified Sequences. Where multiple radiocarbon dates derive from a stratigraphically ordered sequence of archaeological contexts, Bayesian chronological modelling (implemented in software packages including OxCal and BCal) improves on treating each radiocarbon date as an independent estimate by incorporating the stratigraphic ordering as prior information. Formally, if 1, ... , de- note the true calendar dates of stratified contexts with known ordering $1 < 2 < <$, and denotes the radiocarbon determination for context with associated measurement and calibration-curve uncertainty, Bayesian modelling combines the likelihood () (derived from the IntCal20 calibration curve referenced in Chapter 9) with the ordering constraint as a prior, yielding a posterior distribution (1, ... , 1, ... ,) over the full sequence that is typically substantially narrower than the individually calibrated date ranges, particularly valuable for resolving sequences falling within or near the IntCal20 plateau affecting IVC- period dates. **Finding C.1: Plateau Mitigation Through Sequence** Constraints. Because the IntCal20 plateau (approximately 2450–2150 BCE, noted in the Glossary) produces near-flat calibration- curve behaviour that maps a wide range of radiocarbon ages onto a similarly wide range of calendar dates, individual radiocarbon determinations falling within the plateau are poorly resolved in isolation. Bayesian sequence modelling partially mitigates this limitation, not by improving the resolution of any single date, but by using the combined constraint of multiple stratigraphically ordered dates — some of which may fall outside the plateau — to narrow the plausible calendar-date range for dates that do fall within it, a technique applied with some success to refine Mature Harappan phase-transition dating at several well-stratified sites, though the technique's benefit is necessarily limited at sites where most or all available dates happen to cluster within the plateau itself.

C.2 Tree-Ring Wiggle-Matching

Case Study C.1: Dendrochronological Cross-Checking Where Available. Where wood or charcoal samples derive from a securely cross-dated tree-ring sequence of suicient length, "wiggle-matching" — fitting the relative spacing of a sequence of radiocarbon dates from individually identified tree rings against the detailed structure of the calibration curve, rather than calibrating a single bulk date — can achieve chronological resolution substantially finer than the plateau would otherwise permit, since the internal spacing of the ring sequence provides additional constraint information unavailable to single-sample calibration. This technique

has been applied productively to plateau-affected chronological problems in other world regions (notably parts of the Aegean Bronze Age chronology debate) but has seen only limited application to IVC chronology to date, owing to the comparative scarcity of suiciently long, securely identified timber sequences recovered from IVC archaeological contexts, a methodological opportunity this volume notes as a potentially fruitful direction for future chronological refinement.

Appendix D

Technical Notes on Information-Theoretic Measures of Script Structure

D.1 Entropy and Conditional Entropy, Formally Defined

Definition D.1: Shannon Entropy Applied to Sign Sequences. For a sequence of symbols drawn from an alphabet $\Sigma = \{s_1, \ldots, s_n\}$ with empirical probability distribution $p(s)$, the Shannon entropy is

$$H(\Sigma) = -\sum_{i=1}^{n} p(s_i) \log_2 p(s_i),$$

measured in bits, quantifying the average uncertainty in a randomly drawn symbol. The conditional entropy of the next symbol given the preceding symbol,

$$H(s_{t+1} \mid s_t) = -\sum_{s,s'} p(s, s') \log_2 p(s' \mid s),$$

quantifies the residual uncertainty in the next symbol once the current symbol is known, and is the statistic computed by Rao et al. (2009) for the Indus corpus, discussed in Chapter 13. A low conditional entropy relative to the unconditioned entropy $H(\Sigma)$ indicates strong sequential structure (high predictability of what follows what); the specific numerical comparison to known linguistic and non-linguistic sequences, including DNA and artificial token sequences, formed the empirical core of the Rao et al. study's much-debated conclusions.

D.2 N-gram Models and Their Limits

Finding D.1: Why Higher-Order Models Cannot Substitute for External Anchoring. Higher-order n-gram models, extending the bigram conditional entropy of Definition D.1 to condition on the preceding $n-1$ symbols rather than just one, can in principle characterise increasingly fine-grained sequential structure in the Indus corpus, and have been applied in several of the computational studies reviewed in Part IV. However, the corpus-size limitation discussed in Chapter 5 imposes a hard ceiling on how high an order n can be reliably estimated: the number of free parameters in an n-gram model over an alphabet of size $|\Sigma|$ grows as $|\Sigma|^n$, and reliable estimation requires a number of training tokens substantially exceeding the parameter count, a requirement the approximately 4,000-sign Indus corpus satisfies only for very low orders ($n = 1, 2$, occasionally 3) before data sparsity makes higher-order estimates

statistically unreliable. This is a formal, quantifiable instance of the general structural limitation articulated qualitatively in Chapter 14: no amount of algorithmic sophistication applied to n-gram or related distributional models can extract reliable structure beyond what the corpus's information content actually supports, and the corpus's small absolute size — not the modelling technique — is the binding constraint.

D.3 Cross-Entropy Comparison to Known Scripts

Proposition D.1: The Logic and Limits of Comparative Entropy Benchmarking. The comparative method underlying Rao et al. (2009) and subsequent studies — computing the conditional entropy of the Indus sign sequence and comparing it to the conditional entropy of known linguistic sequences (several natural languages, represented at the word or character level), known non-linguistic but structured sequences (DNA coding sequences), and known non-structured or differently structured sequences (artificially generated random sequences, and rigidly ordered non-linguistic sequences such as certain formal sign systems) — establishes only that the Indus sequence's conditional entropy falls within the range occupied by linguistic sequences, rather than within the very low range of rigid formulaic sequences or the very high range of unstructured randomness. This finding, as discussed at length in Chapter 13, is informative but limited: entropy benchmarking is a coarse, single-number summary statistic that can discriminate broad structural categories (highly rigid versus moderately patterned versus unstructured) without discriminating finer distinctions (for instance, between a genuine natural language and a sophisticated non-linguistic notation system with comparable sequential regularity, such as certain accounting or genealogical notations), a limitation the original study's authors themselves acknowledged and that subsequent critics (Sproat prominently) emphasised in the methodological debate reviewed in Chapter 13.

Appendix E

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The following list collects, organised by the volume's four analytical engines and its comparative and historiographic material, the principal works referenced in the preceding chapters. It is offered as a guide to further reading rather than as an exhaustive citation apparatus in the journal-article sense; readers seeking primary-source verification of any specific claim should consult the named study directly.

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Appendix F

Glossary of Technical Terms

Term	Definition
4.2 ka event	A widespread aridification episode dated to approximately 4,200–3,900 years before present, documented in palaeoclimate proxy records across a broad geographic belt. See Chapter 10.
AASI	Ancient Ancestral South Indian; a deeply diverged South Asian hunter-gatherer genomic component inferred from admixture patterns in later populations. See Definition 1.1.
admixture	The process of reproduction between previously isolated or partially isolated populations, resulting in an offspring generation with ancestry from multiple source populations.
agglutinative	Describes a language morphological type in which words are constructed by concatenating morphemes with relatively stable phonological form and discrete semantic content; contrasted with isolating (no morphological affixation) and fusional (morphemes fuse and alter each other's phonological form). Dravidian languages are agglutinative.
boustrophedon	Writing direction alternating between left-to-right and right-to-left on successive lines; attested in some Indus inscriptions and in early Greek and Etruscan writing.
conditional entropy	A measure of the average uncertainty in the next symbol in a sequence given knowledge of the current symbol; used in the Rao et al. (2009) analysis of the Indus corpus.
determinative	In mixed logosyllabic scripts, a sign that classifies the semantic category of the following word without contributing to its phonological reading; common in Egyptian and Mesopotamian writing.
f_4**-statistic**	A statistic measuring correlated allele frequency differences between two pairs of populations; when significantly non-zero, indicates gene flow inconsistent with a strict population tree. See Definition A.1.

Term	Definition
Indus Periphery Cline	The genomic cluster of individuals, sampled from sites at the geographic periphery of the IVC, whose ancestry is predominantly Iranian-farmer-related with an AASI admixture component. See Definition 1.1.
IntCal20	The current (2020) radiocarbon calibration curve, converting raw radiocarbon ages to calendar years; has a plateau covering approximately 2450–2150 BCE that reduces chronological resolution for IVC-period events.
linkage disequilibrium	The non-random association of alleles at different chromosomal loci, which decays with recombination over generations; its decay rate is used to date admixture events. See Definition A.3.
logosyllabic	Describes a script type in which some signs represent morphemes or words (logographs) and others represent syllables (syllabograms); characteristic of Egyptian hieroglyphs and Mesopotamian cuneiform.
qpAdm	A software implementation of an f-statistics-based admixture modelling framework, used to estimate the proportions of multiple source populations contributing to a target population's ancestry. See Definition A.2.
rebus	The use of a sign representing an object or concept to encode the same sounds found in the object's name, regardless of the resulting phonetic sequence's meaning; a common mechanism in the development of phonographic writing from logographic antecedents.
SOV	Subject-Object-Verb; a word order typology in which the standard declarative sentence places the verb at the end. Dravidian and Japanese are SOV; Latin and Sanskrit are flexible but SOV-dominant.
speleothem	Cave formations (stalagmites, stalactites) of calcium carbonate precipitated from percolating groundwater; used as palaeoclimate proxy records through oxygen isotope analysis. See Definition B.1.
Tier 1 / 2 / 3	The three-level classification of claims about the IVC adopted in this volume: Tier 1 (genetic ancestry), Tier 2 (language affiliation), Tier 3 (identity and political claims). See Definition 0.1.